Neurotrauma

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FRCNST, Siriraj hospital

Evidence-based medicine

ยังคงจำเป็นเสมอในการใช้ดูแลผู้ป่วย

Expert opinion esp. surgical procedure

ความเป็นผู้เชี่ยวชาญจะได้ใช้ประโยชน์อย่างมากโดยเฉพาะสิ่งที่เป็นหัตถการ

Common sense will be growth with more strength

สิ่งที่เราได้มาจาก training คือ common sense ที่จะยิ่งโตตามประสบการณ์ที่มากขึ้น

Moral Ethics and expression

หมั่นควบคุมอัตตาของเรา แล้วเราจะเป็นผู้เชี่ยวชาญอย่างแท้จริง

ศ.นพ.ประสิทธิ์ วัฒนาภา
คณบดีคณะแพทยศาสตร์ศิริราชพยาบาล
ในพิธีมอบประกาศนียบัตรแพทย์ประจำบ้าน แพทย์ประจำบ้านต่อยอด และแพทย์เฟลโลว์
28 มิถุนายน 2562

Head trauma

Spine trauma

Head trauma

Outline

- Basic science
- Primary assessment
  - Use primary survey as ATLS guideline
- Specific assessment
  - Physical examination
  - Imaging study
  - Management

Anatomy

Layers of the scalp

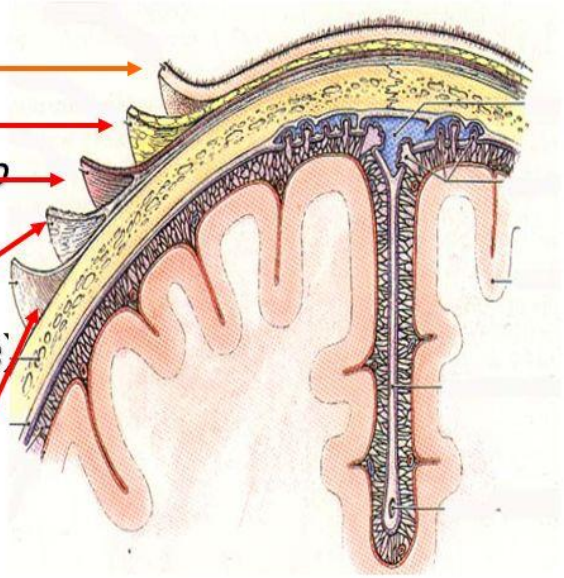
S = *skin*

C = *connective tissue*

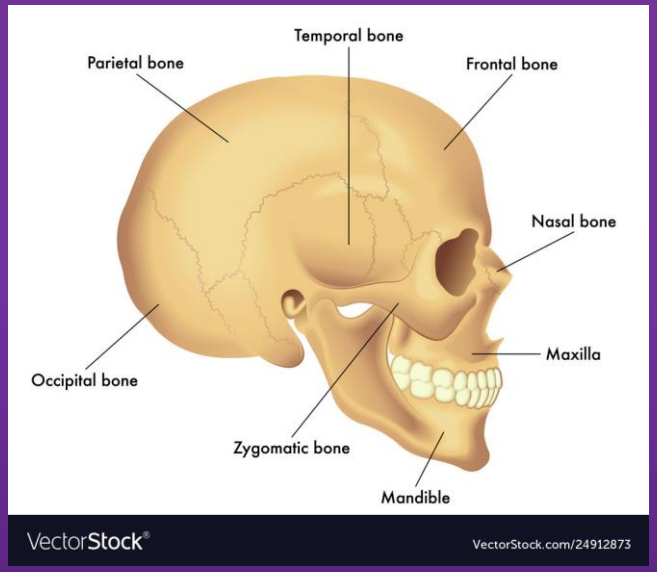
A = *aponeurosis of occipito Frontalis*

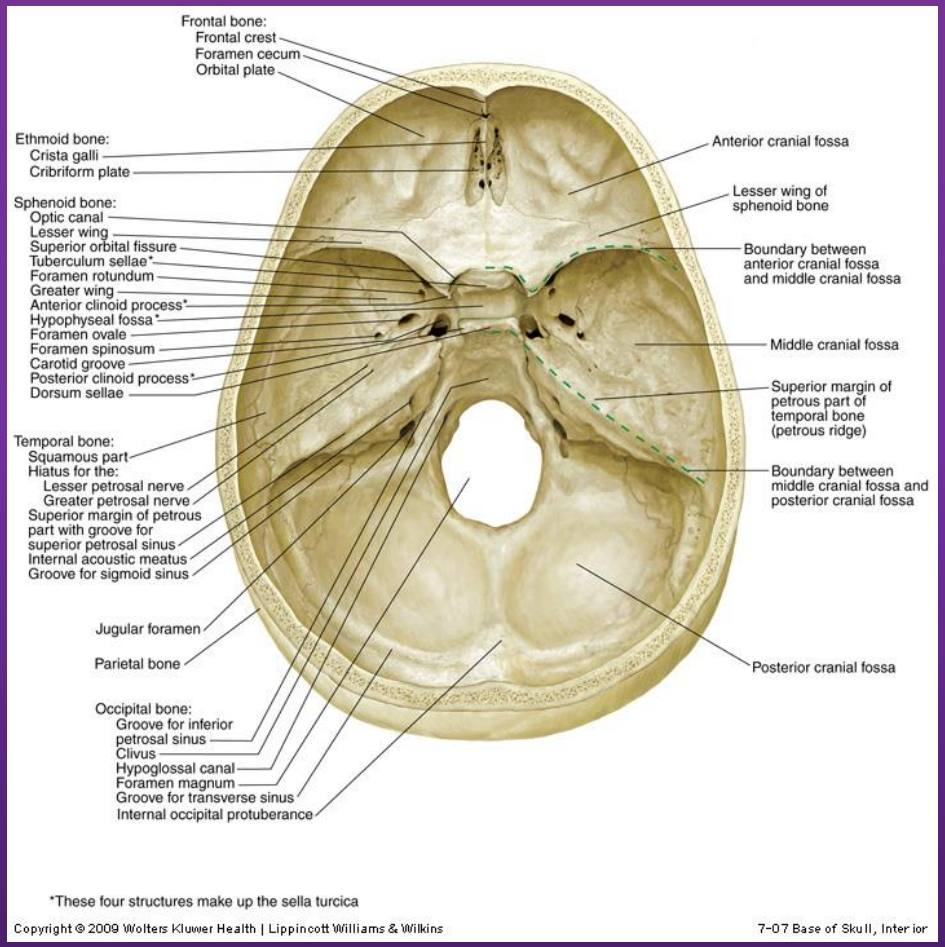
L = *loose areolar C.T.* (subaponeurotic space)

P = *pericranium (periosteum)*



Anatomy


Temporal bone
Parietal bone
Frontal bone
Nasal bone
Maxilla
Occipital bone
Zygomatic bone
Mandible
VectorStock®
VectorStock.com/24912873


Frontal bone:
Frontal crest
Foramen cecum
Orbital plate
Ethmoid bone:
Crista galli
Cribriform plate
Sphenoid bone:
Optic canal
Lesser wing
Superior orbital fissure
Tuberculum sellae*
Foramen rotundum
Greater wing
Anterior clinoid process*
Hypophyseal fossa*
Foramen ovale
Foramen spinosum
Carotid groove
Posterior clinoid process*
Dorsum sellae
Temporal bone:
Squamous part
Hiatus for the:
Lesser petrosal nerve
Greater petrosal nerve
Superior margin of petrous part with groove for superior petrosal sinus
Internal acoustic meatus
Groove for sigmoid sinus
Jugular foramen
Parietal bone
Occipital bone:
Groove for inferior petrosal sinus
Clivus
Hypoglossal canal
Foramen magnum
Groove for transverse sinus
Internal occipital protuberance
Anterior cranial fossa
Lesser wing of sphenoid bone
Boundary between anterior cranial fossa and middle cranial fossa
Middle cranial fossa
Superior margin of petrous part of temporal bone (petrous ridge)
Boundary between middle cranial fossa and posterior cranial fossa
Posterior cranial fossa
*These four structures make up the sella turcica
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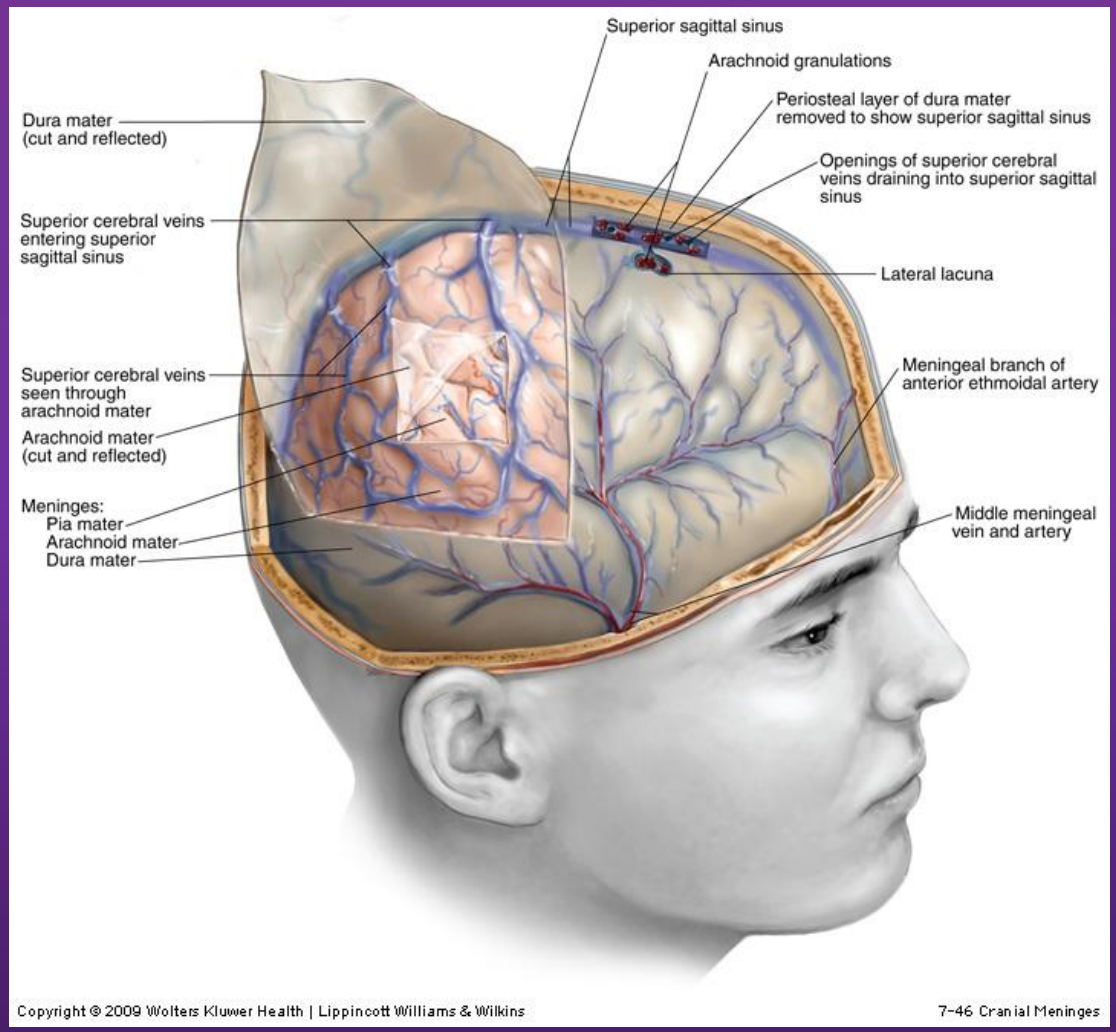
7-07 Base of Skull, Interior

Anatomy


Superior sagittal sinus
Arachnoid granulations
Periosteal layer of dura mater removed to show superior sagittal sinus
Dura mater (cut and reflected)
Openings of superior cerebral veins draining into superior sagittal sinus
Superior cerebral veins entering superior sagittal sinus
Lateral lacuna
Meningeal branch of anterior ethmoidal artery
Superior cerebral veins seen through arachnoid mater
Arachnoid mater (cut and reflected)
Meninges:
Pia mater
Arachnoid mater
Dura mater
Middle meningeal vein and artery
Copyright © 2009 Wolters Kluwer Health | Lippincott Williams & Wilkins
7-46 Cranial Meninges

Anatomy

Head trauma classification by

Mechanism

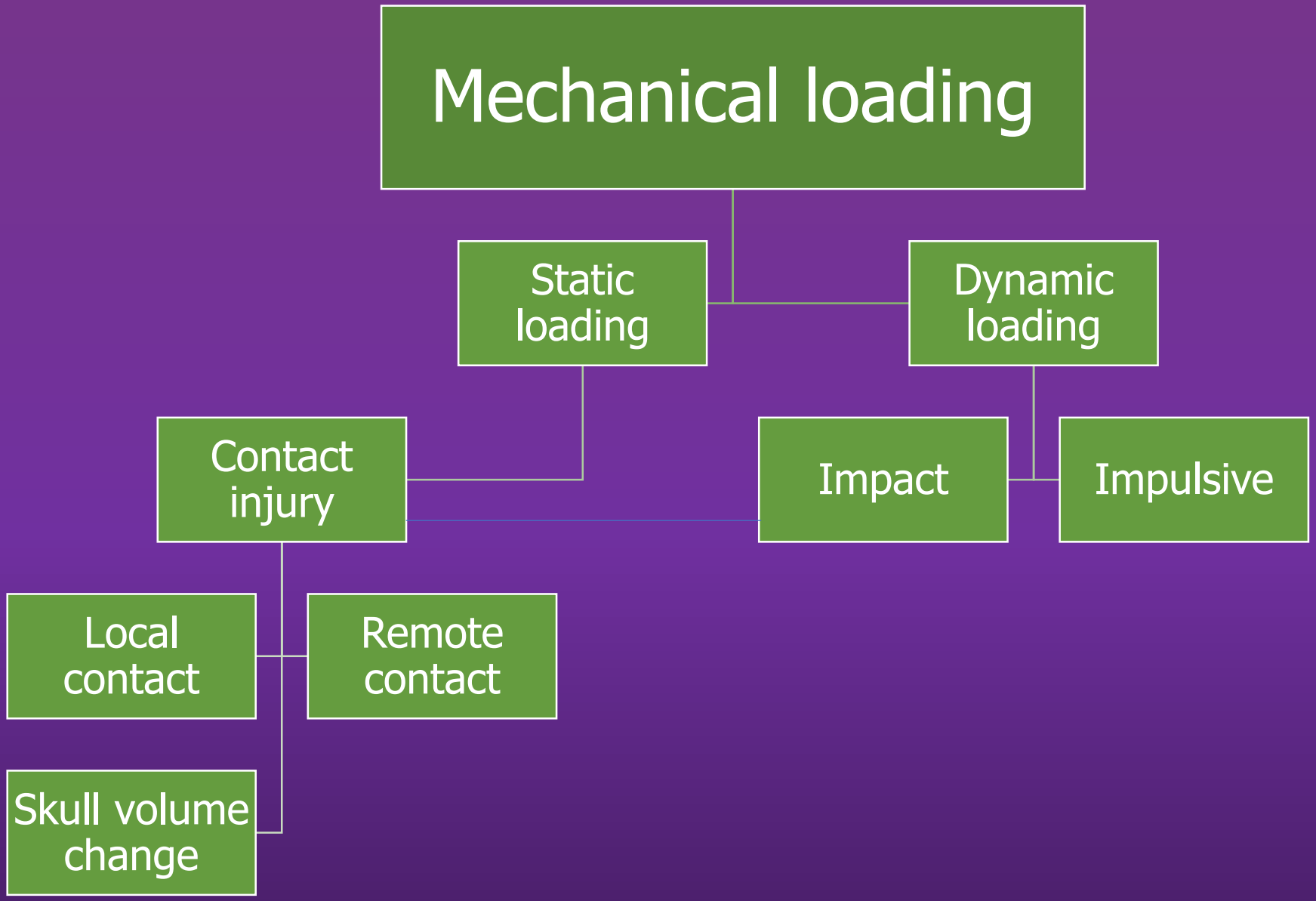
- Static
- Dynamic

Anatomy

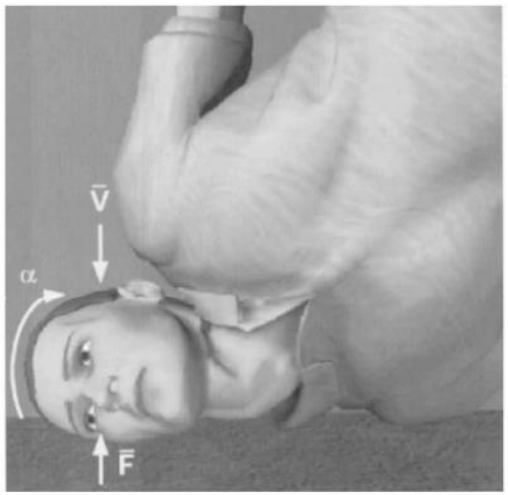
- Scalp
- Skull
- Parenchyma
- Vascular

Pathophysiology

- Primary
- Secondary

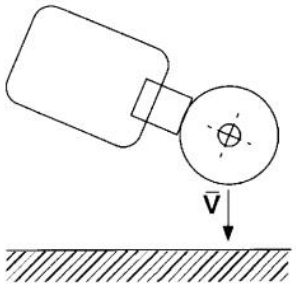

Mechanical loading
Static loading
Dynamic loading
Contact injury
Impact
Impulsive
Local contact
Remote contact
Skull volume change

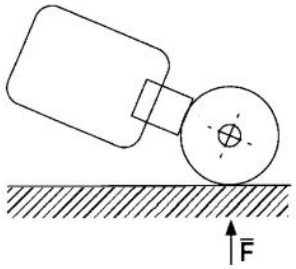
Impact loading

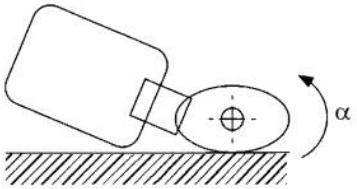


Impact from fall

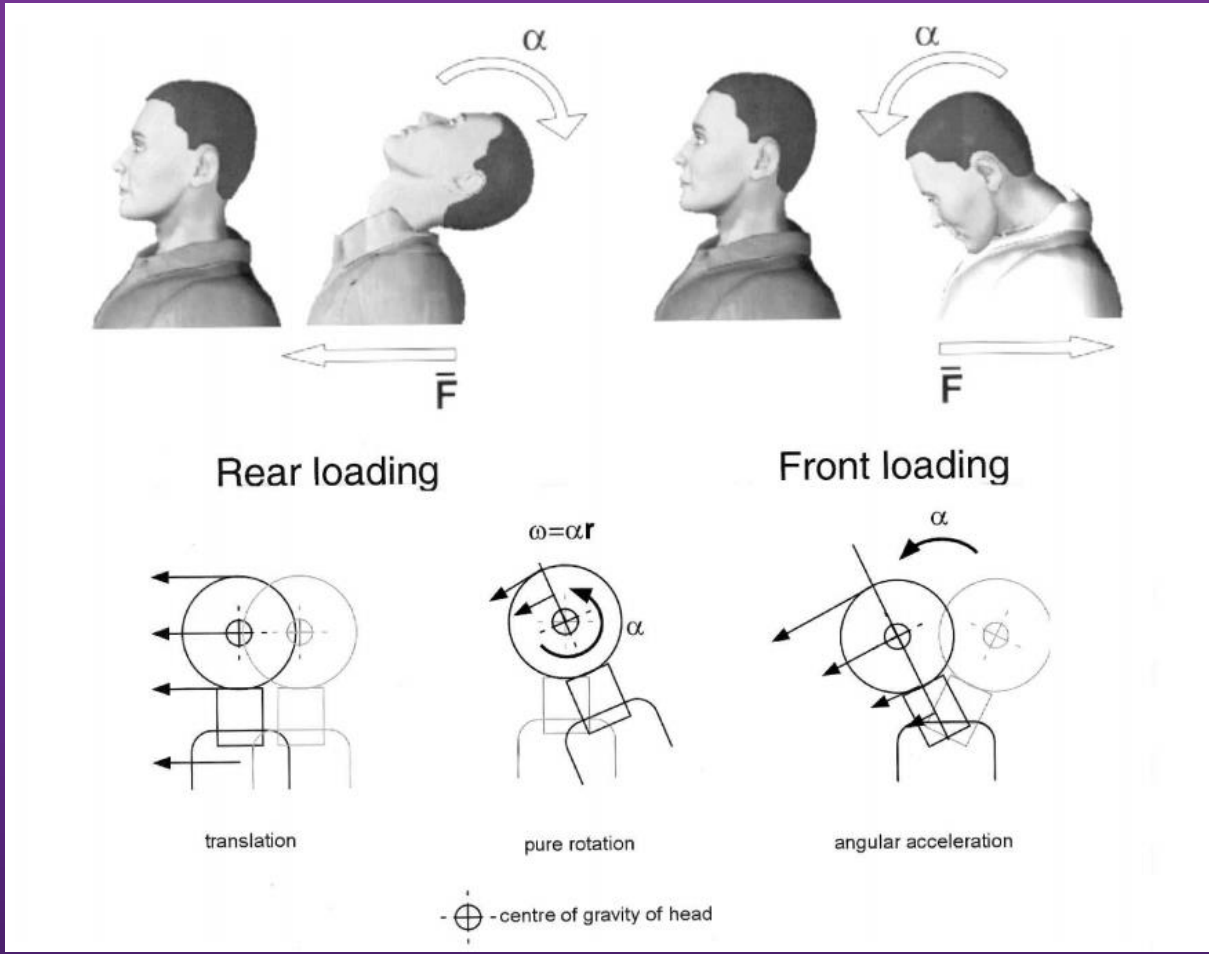
Impact from object



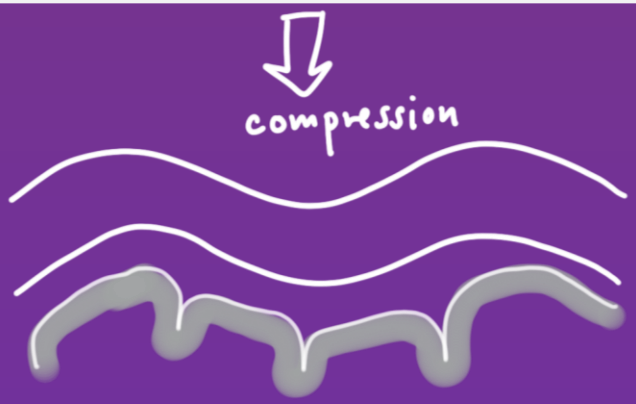




Impulsive loading

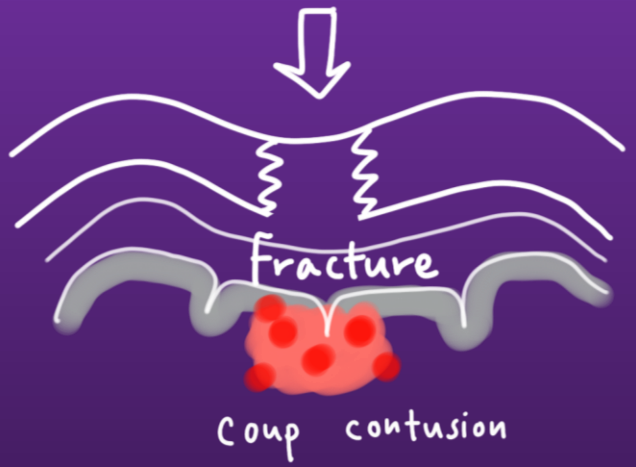


Contact injury



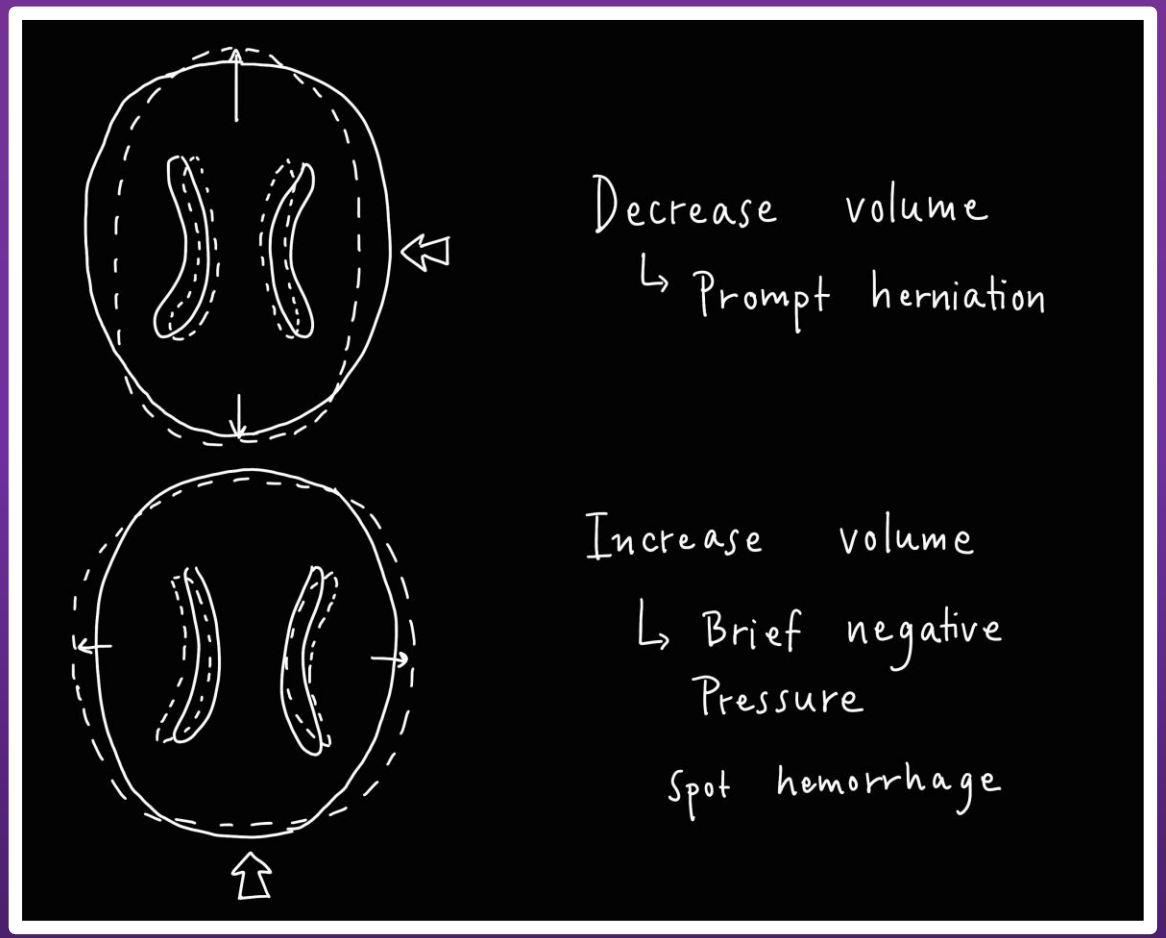
วัตถุจะทน compressive มากกว่า Tensile
ฉะนั้นกะโหลกจะแตกด้านในก่อนเสมอ

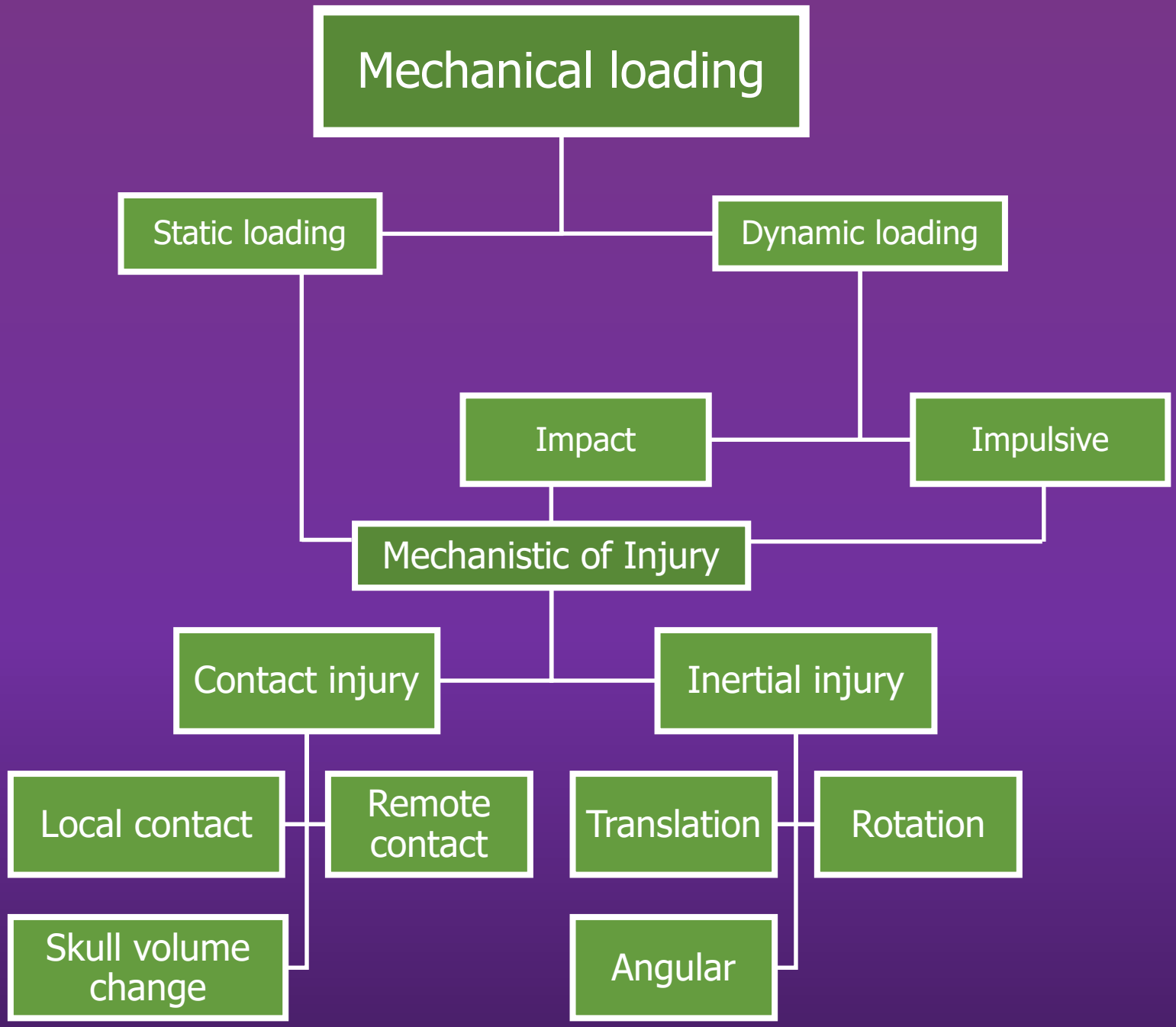
Area less than 2 inch^2

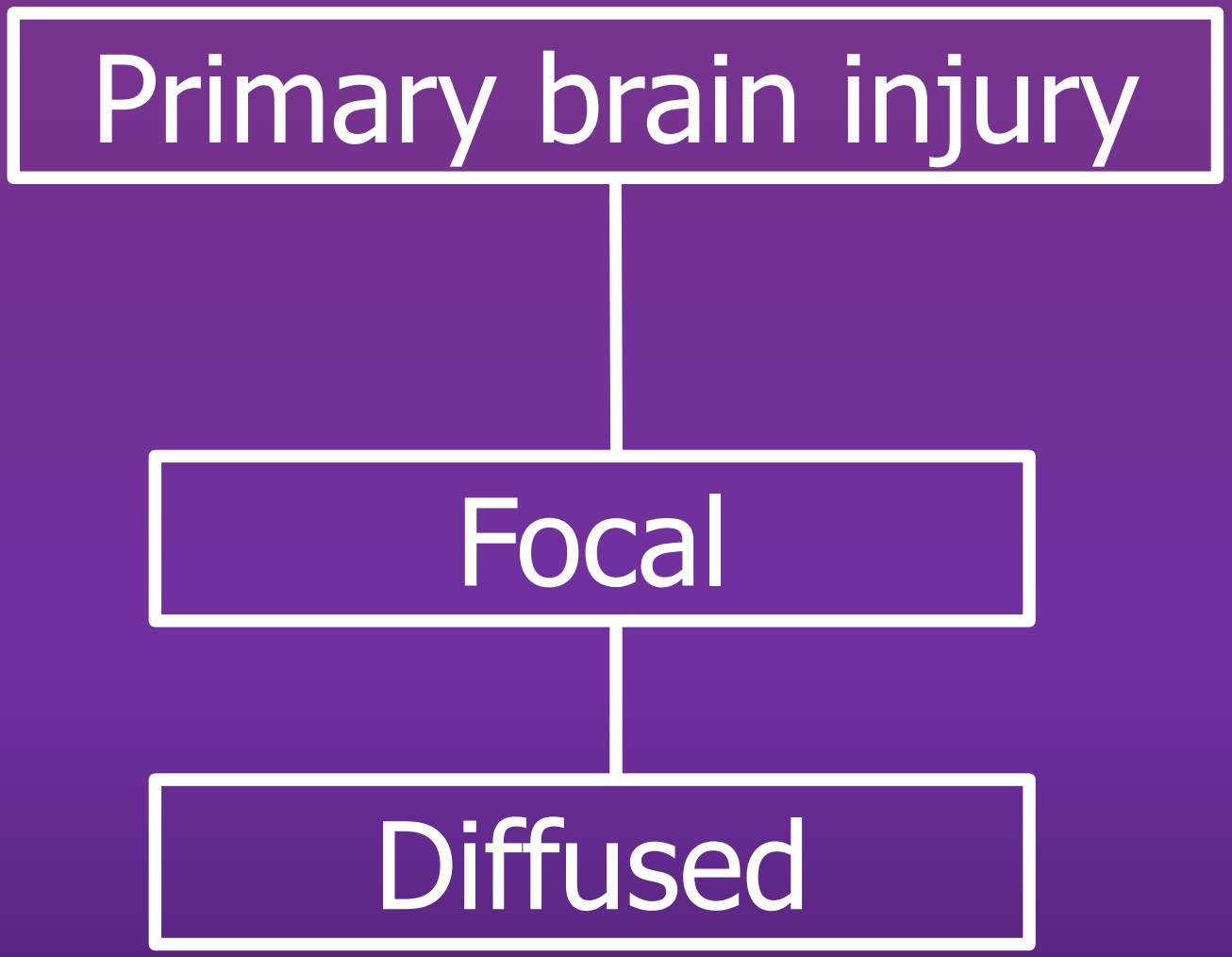


Contact injury

ในเด็กยังมี skull elasticity เพราะฉะนั้นจะเกิด Injury จาก Skull volume change ได้




Mechanical loading
Static loading
Dynamic loading
Impact
Impulsive
Mechanistic of Injury
Contact injury
Inertial injury
Local contact
Remote contact
Translation
Rotation
Skull volume change
Angular


Primary brain injury
Focal
Diffused

Focal brain injury

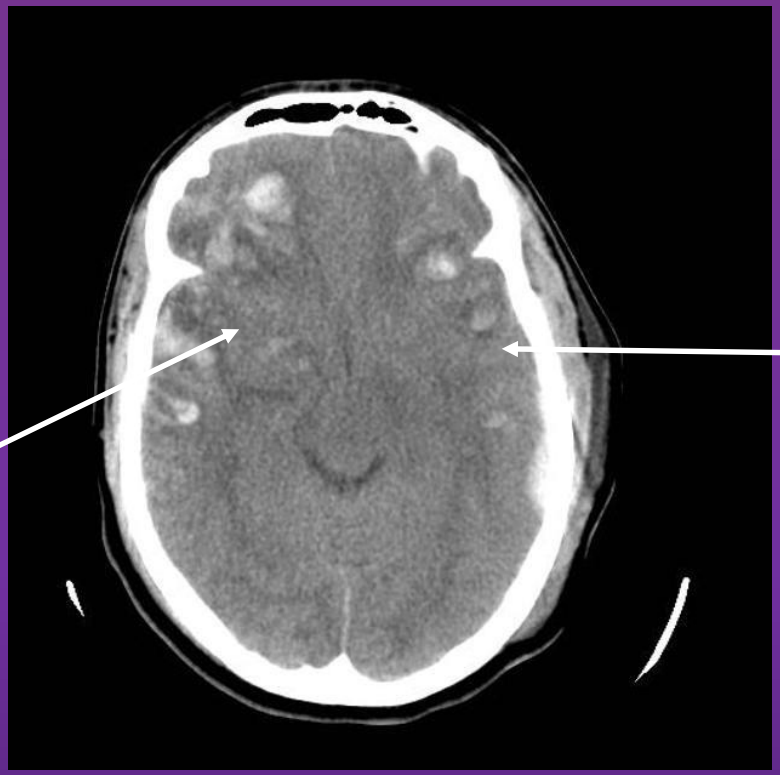
Contusion

- Coup : Site of impact
- Contracoup : Opposite site of impact
- Gliding contusion: Cortex white matter
- Intermediate contusion: Deep brain structure
- Herniation contusion : Medial temporal lobe

Traumatic ICH

- Contusion
- Intracerebral hematoma
- Subdural hematoma
- Epidural hematoma

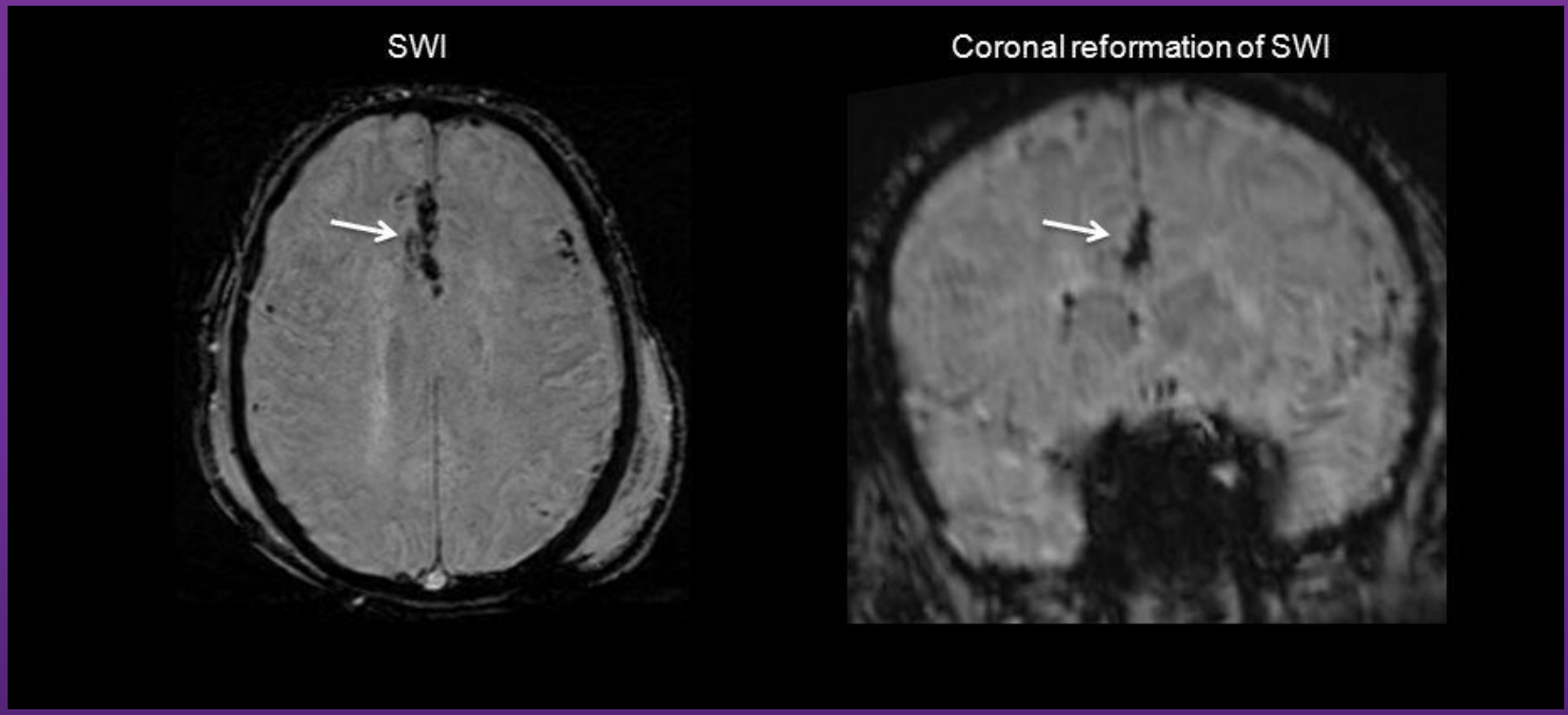
Contracoup



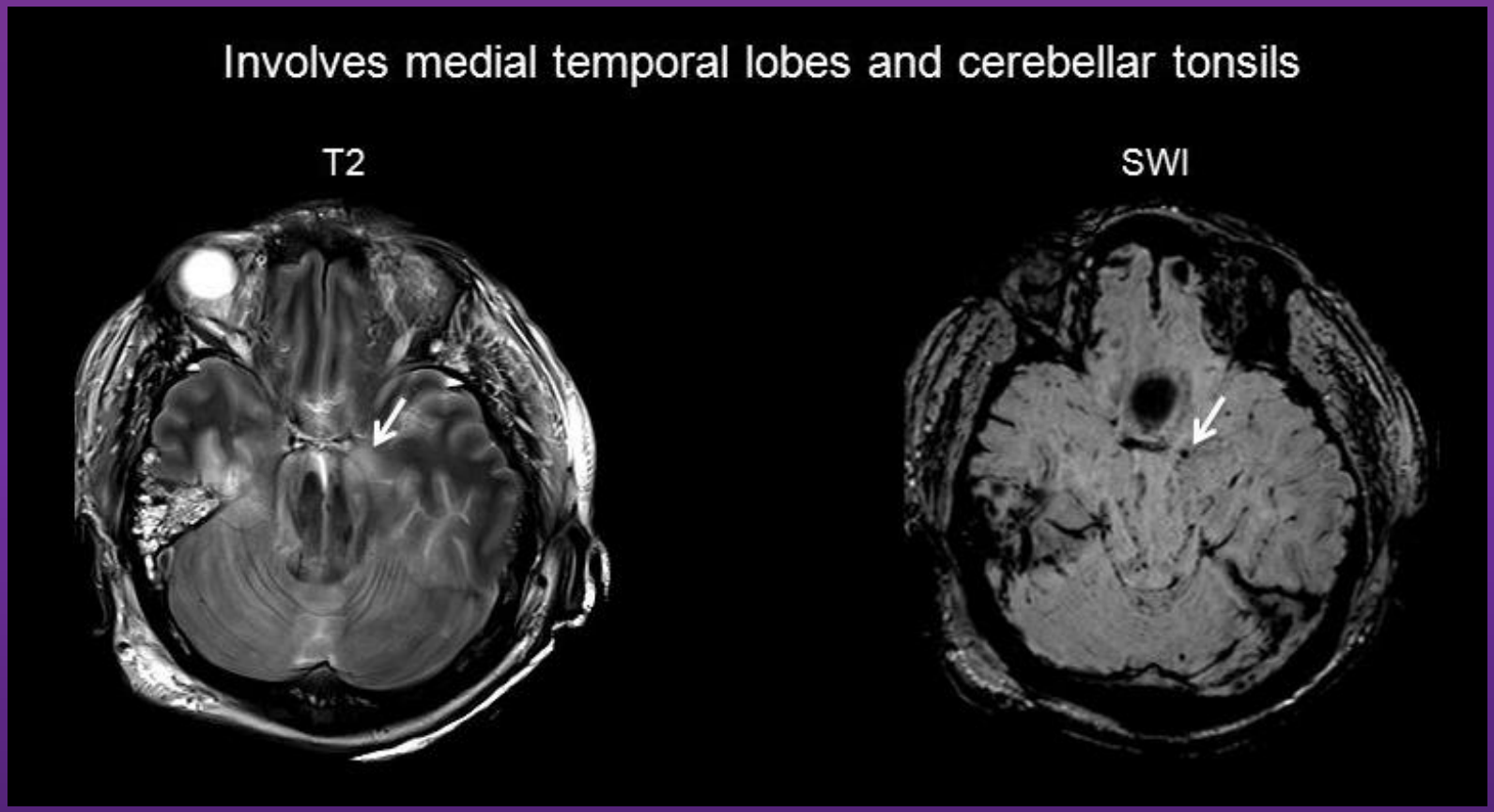
Coup

รู้ได้อย่างไรว่า
อันไหน Coup
อันไหน Contracoup ?

Gliding contusion

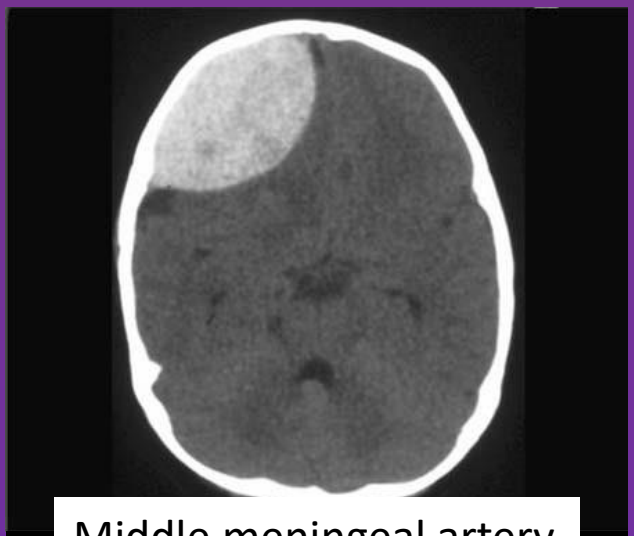


Herniation contusion

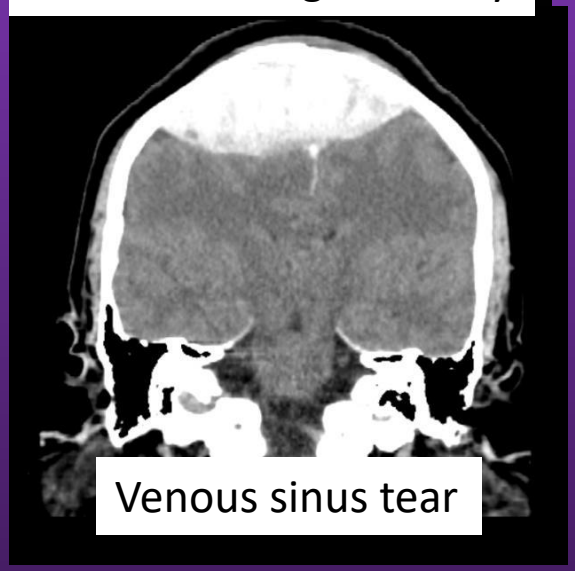


Epidural hematoma

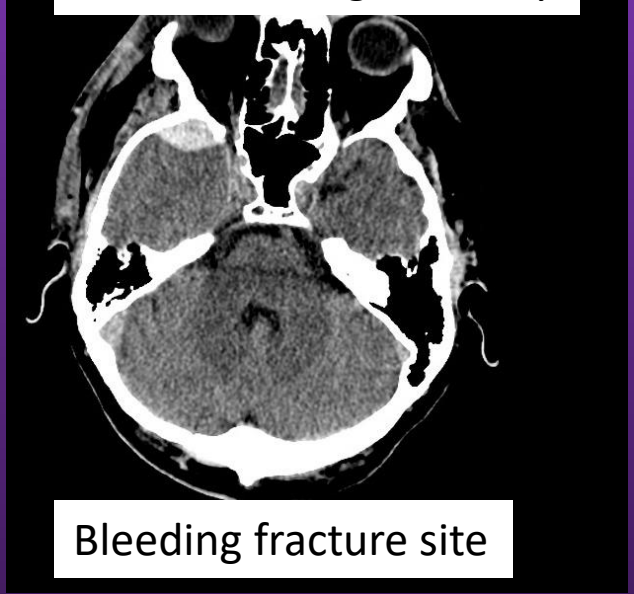
Middle meningeal artery



Middle meningeal artery



Venous sinus tear



Bleeding fracture site

Epidural hematoma

Cross midline ได้ แต่มักไม่ Cross suture ยกเว้น Midline

Less common in children เพราะ Skull compliance ดี และ MMA ยัง Under develop

Less common in elderly เพราะ dural adherent

Subtype
Type I → Swirl unclot blood, acute, day 1
Type II → Subacute, clotted blood, day 2-4
Type III --> Chronic, lysis clot, day 4-20

Subdural hematoma

Causes

- Burst lobe
- Bridging vein tear

Coup site

- ไม่ข้าม midline
- ไม่ข้าม tentorial

Imaging

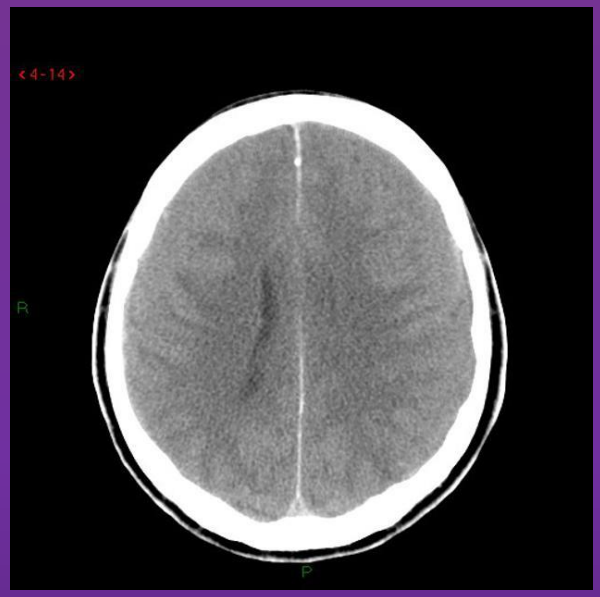
- Crescent on CT

Subdural hematoma MRI stage

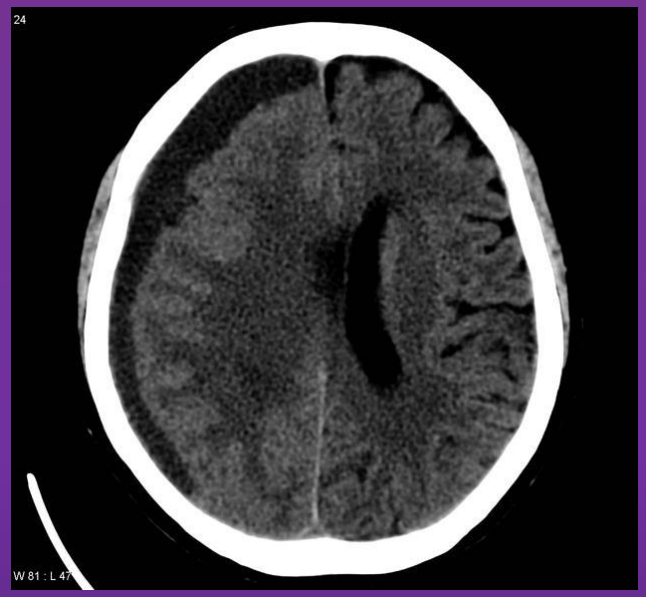
Stage	Age	T1WI	T2WI	Hb stable
Hyperacute	< 12-24 hours	Iso-to-Hypo	Hyper	Oxy-Hb
Acute	1-3 Days	Hypo	Very Hypo	Deoxy-Hb
Early Subacute	2-3 Days → 1-2 wks	Very Hyper	Very Hypo	Met-Hb
Late Subacute	1-2 wks → 1-2 mo	Very Hyper	Very Hyper	Met-Hb(Ec)
Chronic	Few wks → mos/yrs	Iso	Very Hypo	Hemosiderin (SD membrane)
Chronic	Few wks → mos/yrs	Hypo	Hyper	Nonparamagnetic hemochromes(SD content)

Subdural hematoma on CT

Acute SDH



Subacute SDH



Chronic SDH

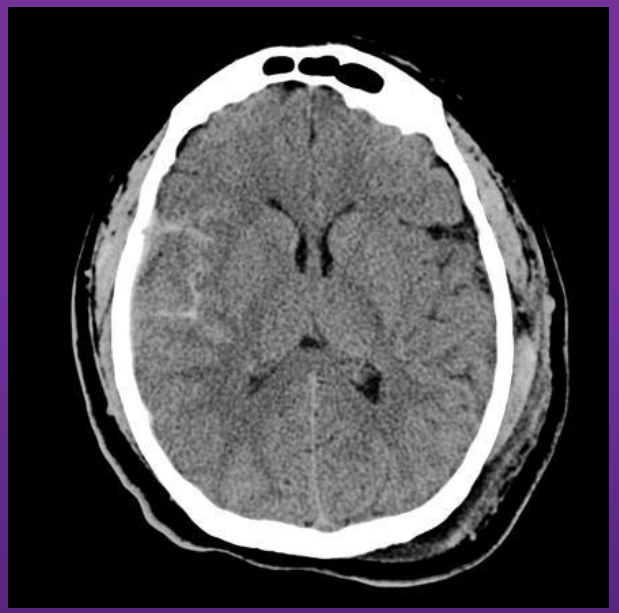
Diffused brain injury

Concussion

- Loss of consciousness
- Return to normal

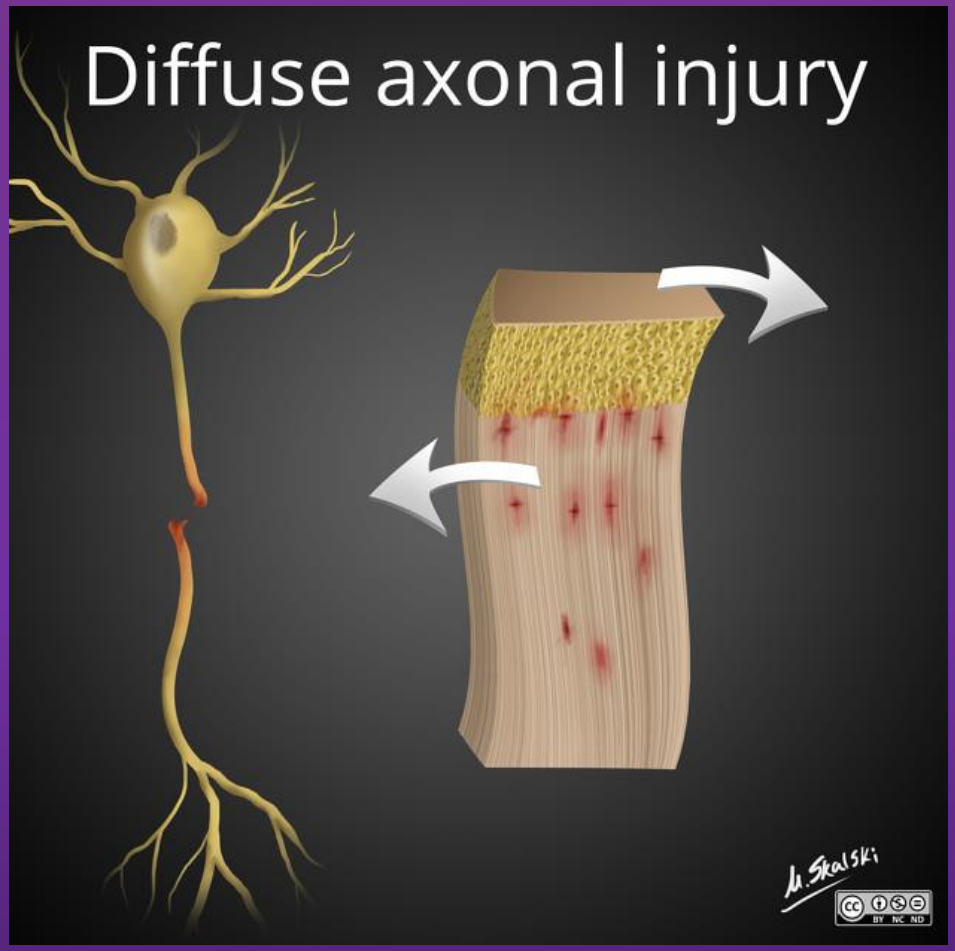
Traumatic SAH

Diffuse axonal injury



Diffuse axonal injury

Neuropathologic	Clinical
Type I: Axonal Injury of parasagittal hemispheric white matter	6-24 hr
Type II: Axonal Injury of parasagittal hemispheric white matter, corpus callosum	> 24 hr.
Type III: Axonal Injury of parasagittal hemispheric white matter, corpus callosum and brainstem	> 24 hr. plus abnormal posturing


Diffuse axonal injury
M. Skalski
BY NC ND

Traumatic intraparenchymal hematoma

พบได้15% ของผู้ป่วยที่เสียชีวิตจาก severe head injury ที่ได้รับการ autopsy

เชื่อว่าเกิดจากการมี shearing force กระทำต่อ lenticulostriate artery จนฉีกขาด

Secondary brain injury

คืออะไร? The results of Neurophysiological and anatomical changes Minutes to Days after original trauma

- Cerebral edema
- Intracranial hemorrhage
- Brain herniation
- Cerebral ischemia
- Infection
- Epilepsy

Secondary brain injury

Circulatory phases after TBI

PHASE	DAYS AFTER INJURY	CBF (mL/100 g/min)	$AVDO_2$ (vol %)	$CMRO_2$ (mL/100 g/min)	$V_{(mca)}$ (cm/sec)	HI
Hypoperfusion	0	Low (32.2 ± 2)	Normal (5.4 ± 0.5)	Depressed (1.77 ± 0.18)	Normal (56.7 ± 2.9)	Normal (1.67 ± 0.11)
Hyperemia	1-3	Relatively increased (46.8 ± 3)	Decreased (3.8 ± 0.1)	Depressed (1.49 ± 0.82)	Increased (86 ± 3.7)	Normal/increased (2.41 ± 0.1)
Vasospasm	14-15	Decreased (35.7 ± 3.8)	Increased (5.9 ± 0.1)	Depressed (1.46 ± 0.65)	Increased (96.7 ± 6.3)	Increased (2.87 ± 0.22)

$AVDO_2$, arteriovenous difference of oxygen; CBF, cerebral blood flow; $CMRO_2$, cerebral metabolic rate of oxygen; HI, hemispheric index; $V_{(mca)}$, middle cerebral artery velocity.

ป้องกันโดย Optimize perfusion

Secondary brain injury

โดยทั่วไปแล้ว ตามทรัพยากรที่เรามี สามารถ Monitor ได้ 2 อย่างได้แก่

Neurological status คือตรวจร่างกาย ดู clinical นั่นเอง

ICP monitoring

เมื่อไหร่จะทำ

1. Severe TBI with abnormal CT
2. Severe TBI with normal CT plus the 2 of followings
   - Age > 40 yrs.
   - Abnormal posturing
   - SBP < 90 mmHg

Primary survey

A

B

C

D

GCS
Pupil size and response
Lateralizing signs and Spinal cord injury

Severity Base on GCS

ความยุ่งยากไม่ได้อยู่ที่ Moderate หรือ Severe traumatic brain injury

ความยุ่งยากอยู่ที่ Mild traumatic brain injury เป็นคนไข้ที่เราถูกฟ้องร้องได้มากที่สุด จึงต้องมีแนวทางที่เป็นมาตรฐาน

Mild TBI	GCS 13-15
Moderate TBI	GCS 9-12
Severe TBI	GCS 3-8

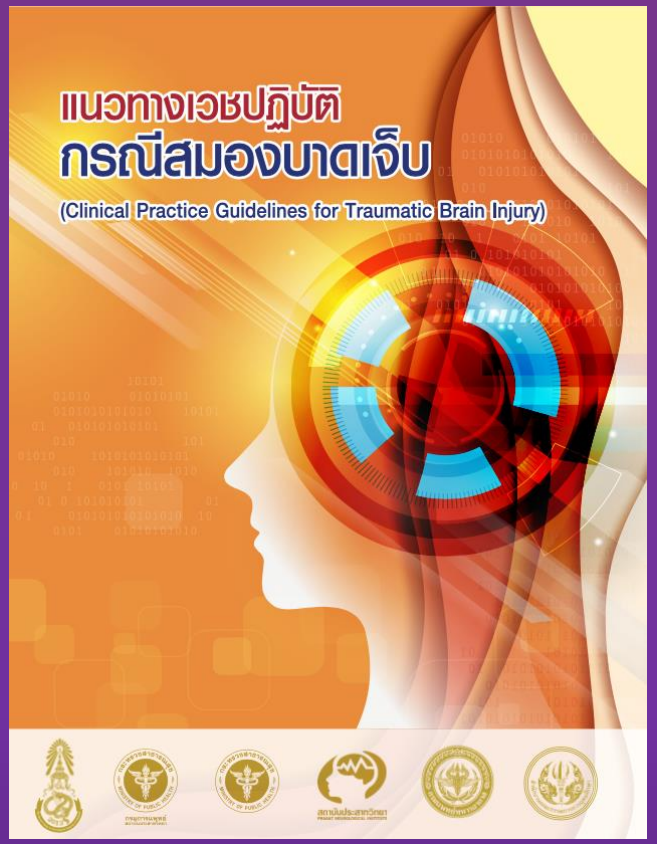
Standard care of TBI

ATLS guideline

4th Brain trauma foundation guideline

Brain Trauma FOUNDATION

อยากใช้อันไหนก็ใช้ แต่ขอให้เป็นมาตรฐานเดียวกัน ข้อมูลต่างกันเล็กน้อย



ของบ้านเราอิงตาม ราชวิทยาลัย
ประสาทศัลยแพทย์แห่งประเทศไทย

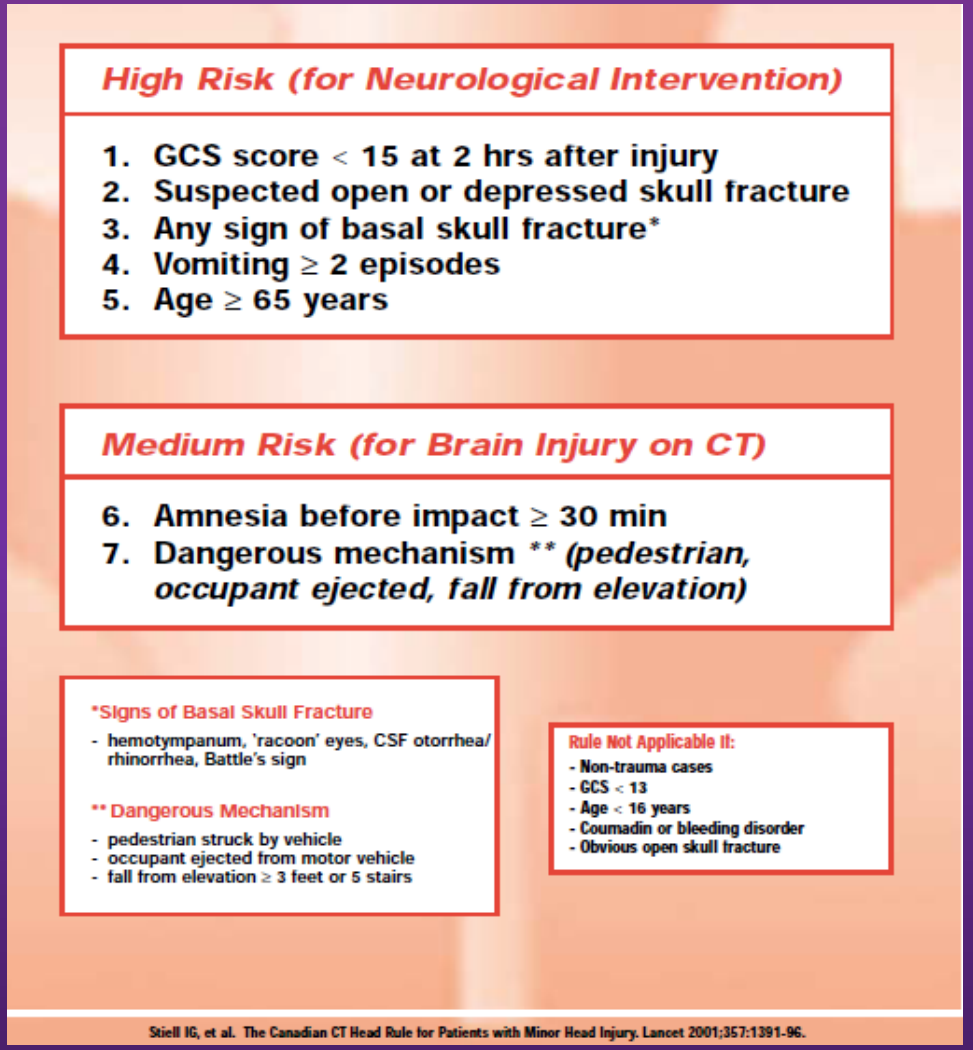
https://www.rcnst.or.th/knowledge/+Clinical+Practice+Guidelines+for+Traumatic+Brain+Injury/

Management by severity

Mild TBI GCS 13-15

เมื่อไหร่จะทำ CT scan

อาศัย
Canadian CT Head rule



Alternative choices

New Orleans Rule

Inclusion Criteria

Age >18
GCS 15
Blunt head trauma occurring within previous 24hr causing LOC, amnesia, or disorientation

Rule *Head CT not required if NONE of the following are present*

Headache
Vomiting
Age >60yr
Drug or Alcohol Intoxication
Persistent anterograde amnesia (deficits in short-term memory)
Visible trauma above the clavicles
Seizure

Alternative choices

Nexus II Rule

Head CT not required if NONE of the following are present

Age ≥ 65yr

Evidence of significant Skull Fracture

Scalp hematoma

Neurologic deficit

Altered Level of Alertness

Abnormal behavior

Coagulopathy

Recurrent or forceful vomiting

Alternative choice

ACEP Clinical Policy (2008)

Inclusion Criteria

- Non-penetrating trauma to the head
- Presentation to ED within 24 hours of injury
- GCS 14 or 15 on initial evaluation in ED
- Age ≥ 16

Exclusion Criteria

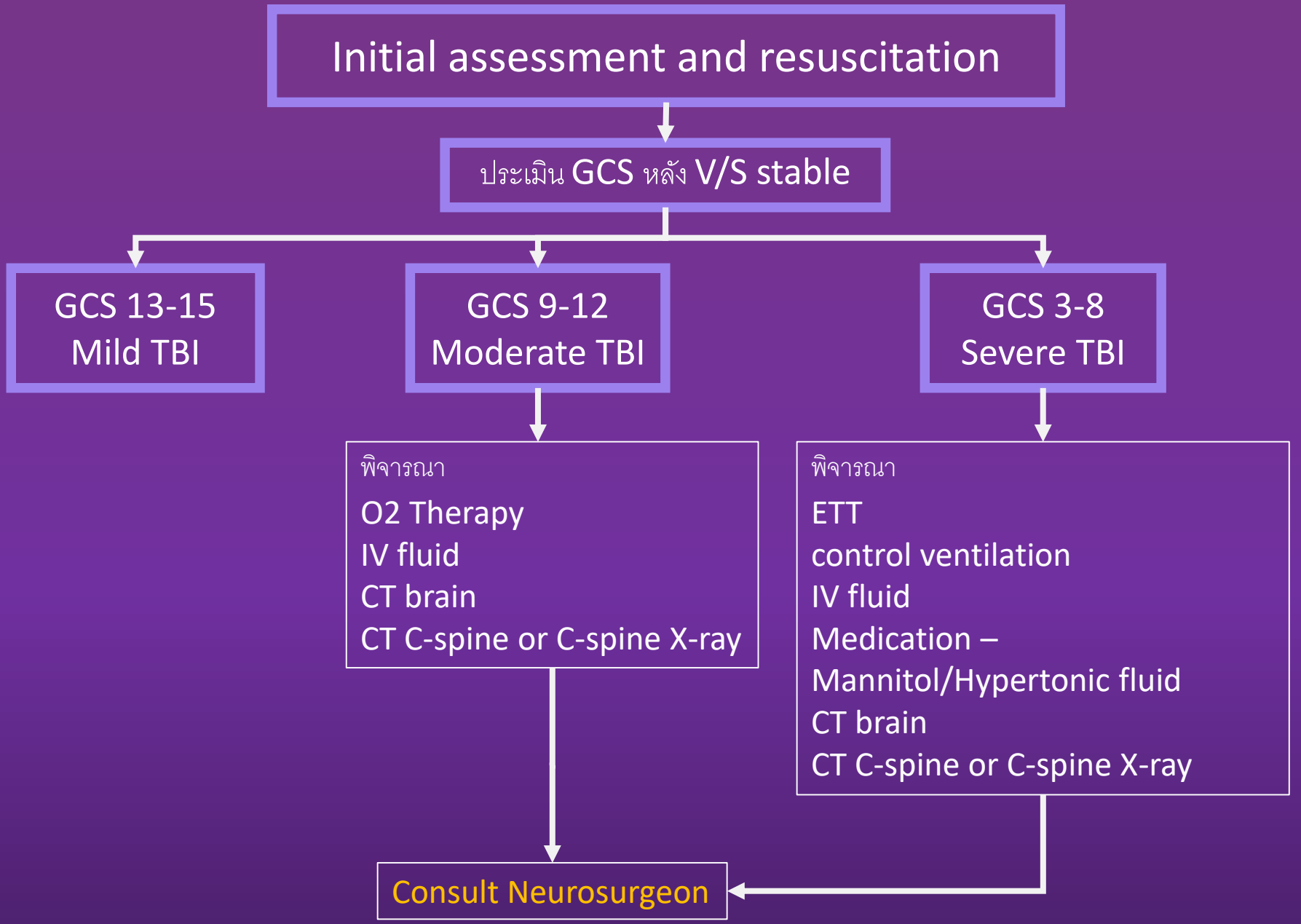
- Penetrating trauma
- Patients with multi-system trauma
- GCS < 14 on initial evaluation in the ED
- Age < 16

Rule *Head CT not required if NONE of the following are present*

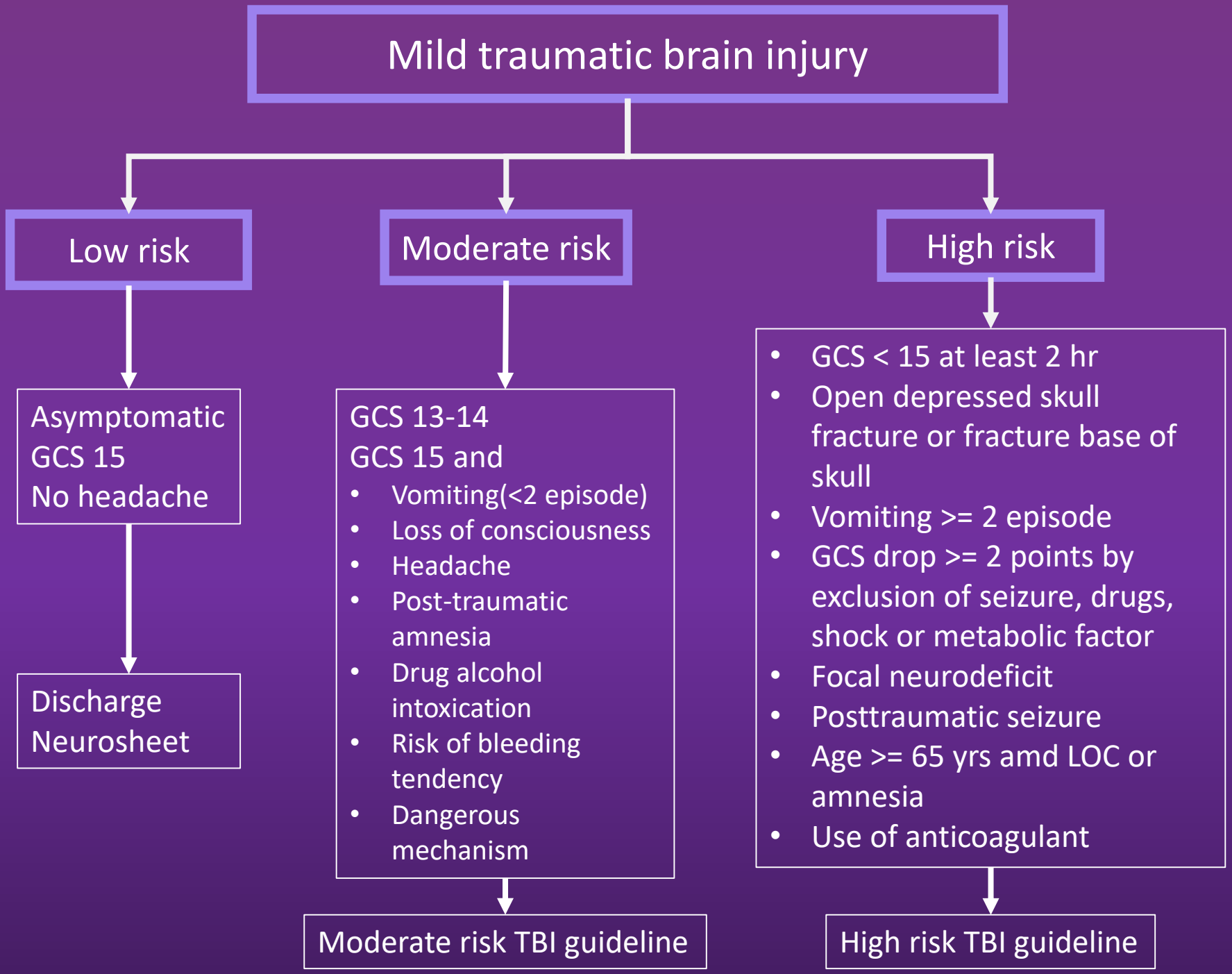
Headache
Vomiting
Age >60yr
Drug or Alcohol Intoxication
Persistent anterograde amnesia (deficits in short-term memory)
Visible trauma above the clavicles
Seizure

CT: sensitivity and specificity

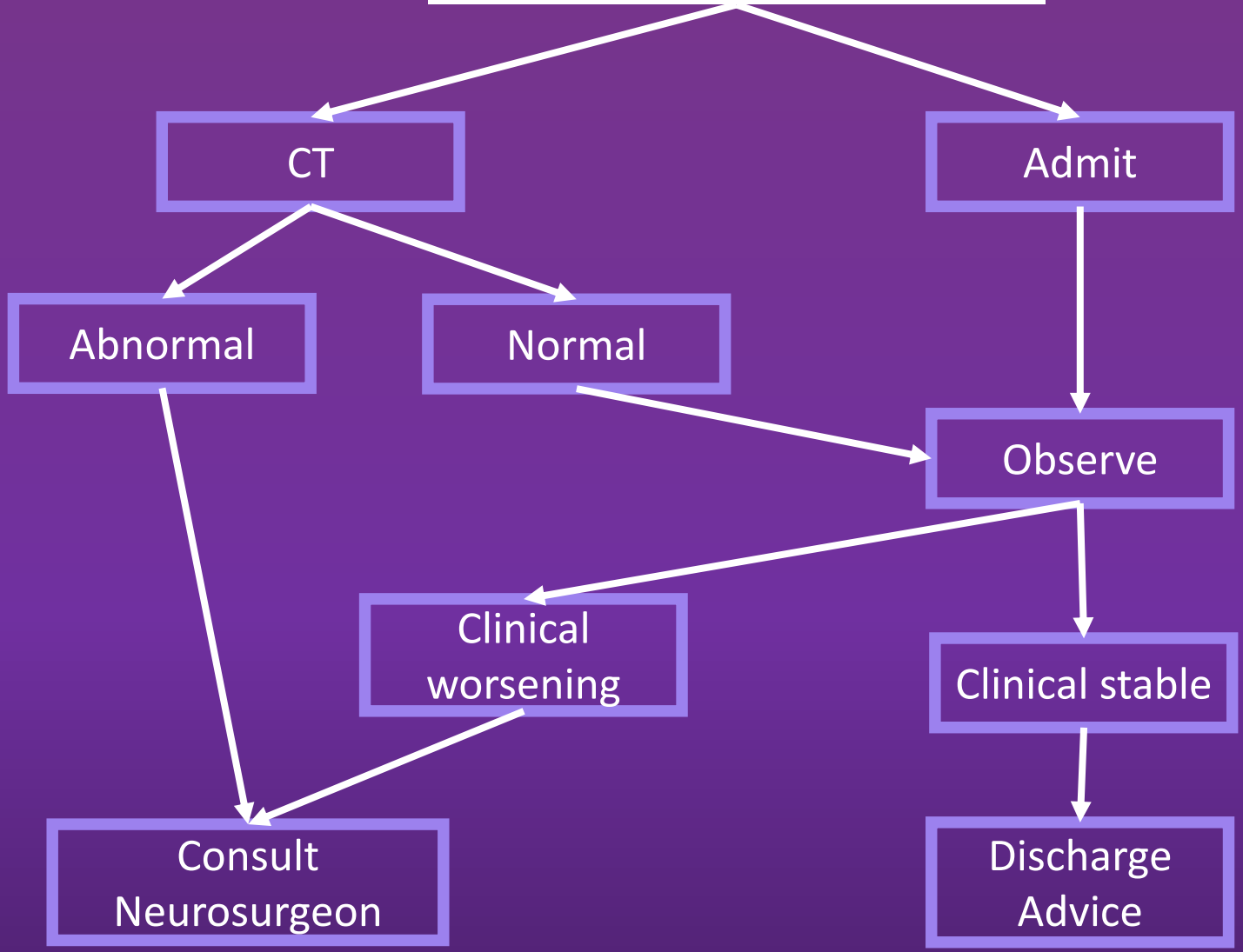
	Canadian Head CT Rule	New Orleans	NEXUS II	ACEP Clinical Policy
Sensitivity	99%	99%	97%	Unknown
Specificity	47%	33%	47%	Unknown



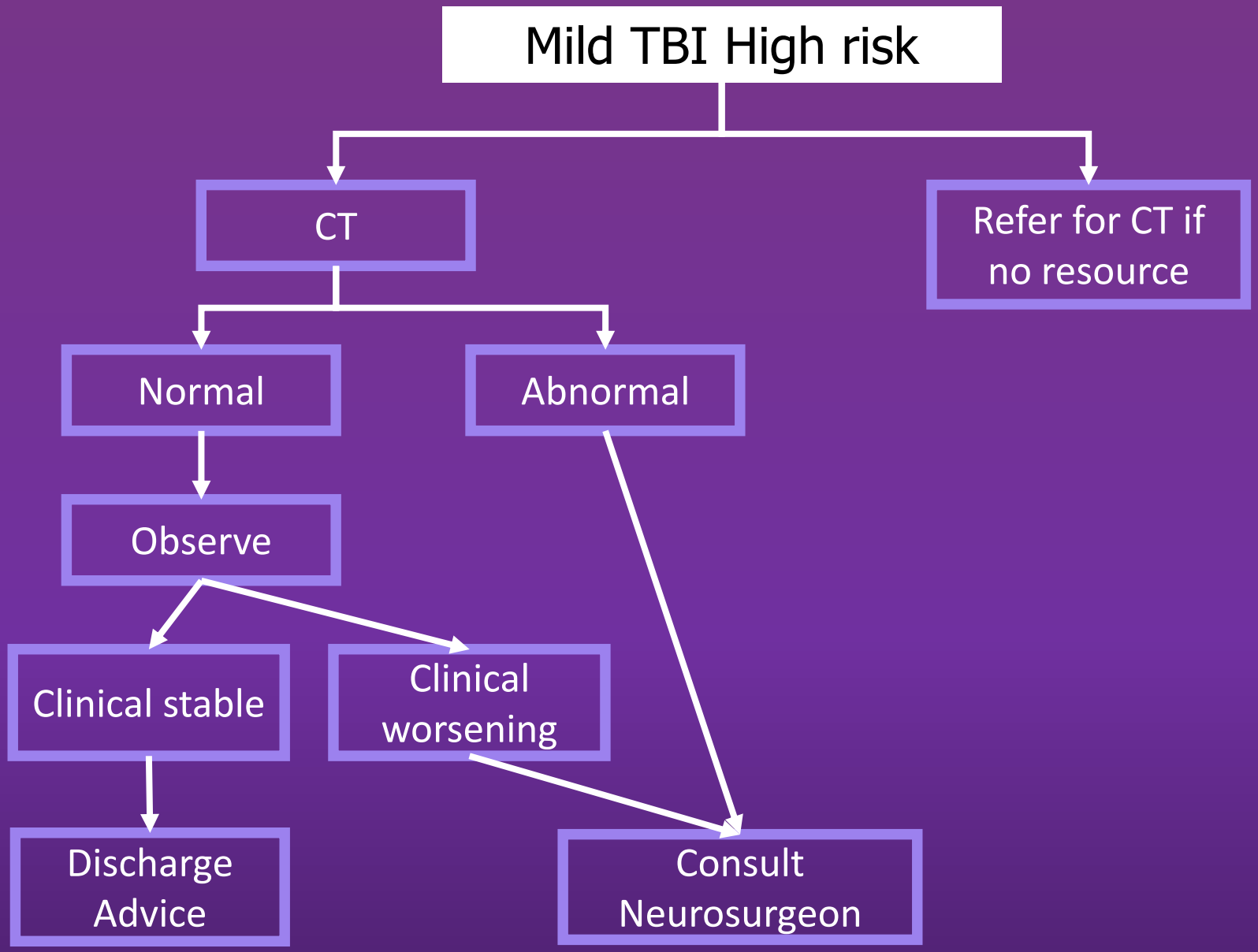
CPG for TBI, Royal college of Neurological Surgeons of Thailand


Mild traumatic brain injury
Low risk
Moderate risk
High risk
Asymptomatic
GCS 15
No headache
Discharge
Neurosheet
GCS 13-14
GCS 15 and
Vomiting(<2 episode)
Loss of consciousness
Headache
Post-traumatic amnesia
Drug alcohol intoxication
Risk of bleeding tendency
Dangerous mechanism
Moderate risk TBI guideline
GCS < 15 at least 2 hr
Open depressed skull fracture or fracture base of skull
Vomiting >= 2 episode
GCS drop >= 2 points by exclusion of seizure, drugs, shock or metabolic factor
Focal neurodeficit
Posttraumatic seizure
Age >= 65 yrs amd LOC or amnesia
Use of anticoagulant
High risk TBI guideline

Mild TBI Moderate risk



* **มีอาการผิดปกติ** หมายถึง GCS score ลดลงจากเดิม ปวดศีรษะมากขึ้น อาเจียนมาก หรือ GCS score < 15 หลังสังเกตอาการแล้ว 2 ชั่วโมง



CPG for TBI, Royal college of Neurological Surgeons of Thailand

Physical examination

Very Basic: GCS

ตรวจผิดตรวจถูกกันเป็นประจำ

CHECK

For factors Interfering with communication,
ability to respond and other injuries

OBSERVE

Eye opening , content of speech and movements of right and left sides

STIMULATE

Sound: spoken or shouted request
Physical: Pressure on finger tip, trapezius or supraorbital notch

RATE

Assign according to highest response observed

Eye opening

Criterion	Observed	Rating	Score
Open before stimulus	✔	Spontaneous	4
After spoken or shouted request	✔	To sound	3
After finger tip stimulus	✔	To pressure	2
No opening at any time, no interfering factor	✔	None	1
Closed by local factor	✔	Non testable	NT

Verbal response

Criterion	Observed	Rating	Score
Correctly gives name, place and date	✔	Orientated	5
Not orientated but communication coherently	✔	Confused	4
Intelligible single words	✔	Words	3
Only moans / groans	✔	Sounds	2
No audible response, no interfering factor	✔	None	1
Factor interferring with communication	✔	Non testable	NT

Best motor response

Criterion	Observed	Rating	Score
Obey 2-part request	✔	Obeys commands	6
Brings hand above clavicle to stimulus on head neck	✔	Localising	5
Bends arm at elbow rapidly but features not predominantly abnormal	✔	Normal flexion	4
Bends arm at elbow, features clearly predominantly abnormal	✔	Abnormal flexion	3
Extends arm at elbow	✔	Extension	2
No movement in arms / legs, no interfering factor	✔	None	1
Paralysed or other limiting factor	✔	Non testable	NT

Sites For Physical Stimulation

Finger tip pressure | Trapezius Pinch | Supraorbital notch

Features of Flexion Responses

Modified with permission from Van Der Naalt 2004
Ned Tijdschr Geneeskd

Abnormal Flexion

Slow Sterotyped
Arm across chest
Forearm rotates
Thumb clenched
Leg extends

Normal flexion

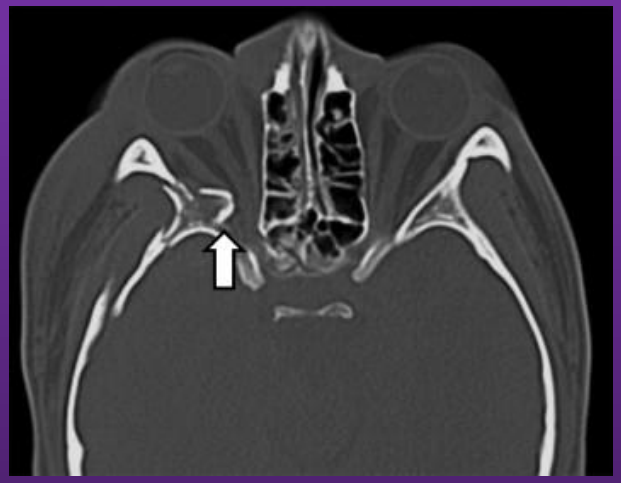
Rapid
Variable
Arm away from body

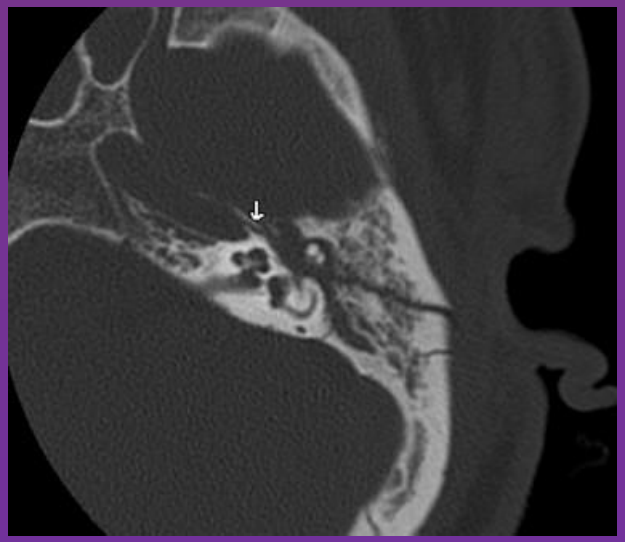
Reference https://www.glasgowcomascale.org/

Physical examination

Common Pitfall

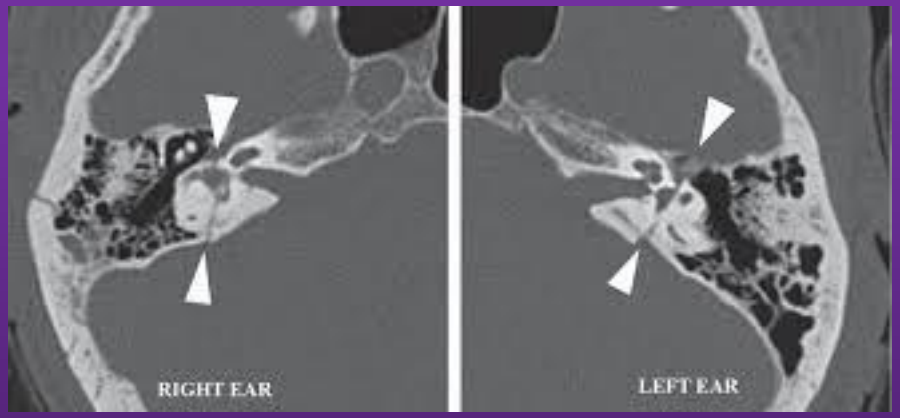
- ❑ Visual loss
- ❑ Facial palsy in skull base fracture
- ❑ Hearing loss in skull base fracture





Longitudinal : 80%

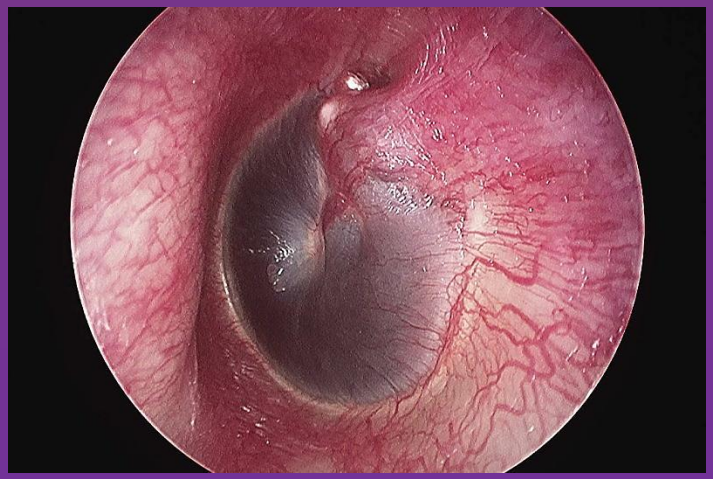
15-20% facial nerve involvement

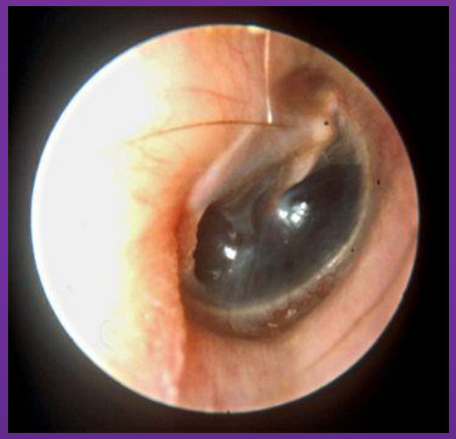


Transverse : 20%

50% facial nerve involvement

CSF Otorrhea





Hemotympanum

Battle sign

Middle skull base fracture

Raccoon’s eyes sign

Anterior skull base fracture

Management of traumatic brain injury

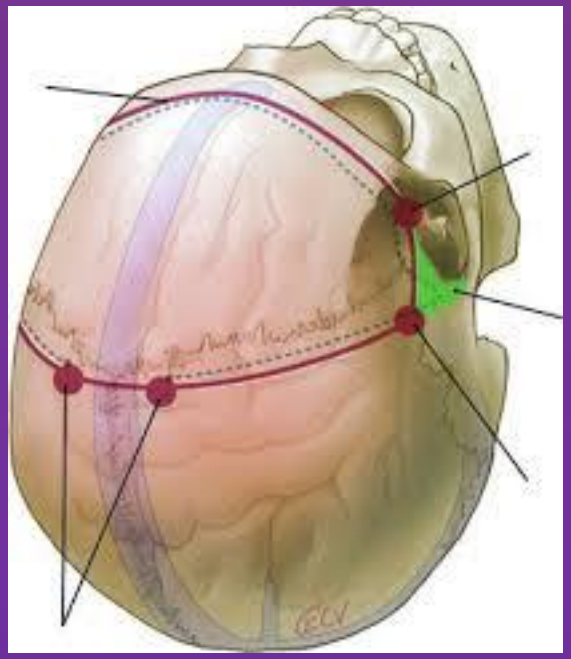
- General management
- Specific management

General management

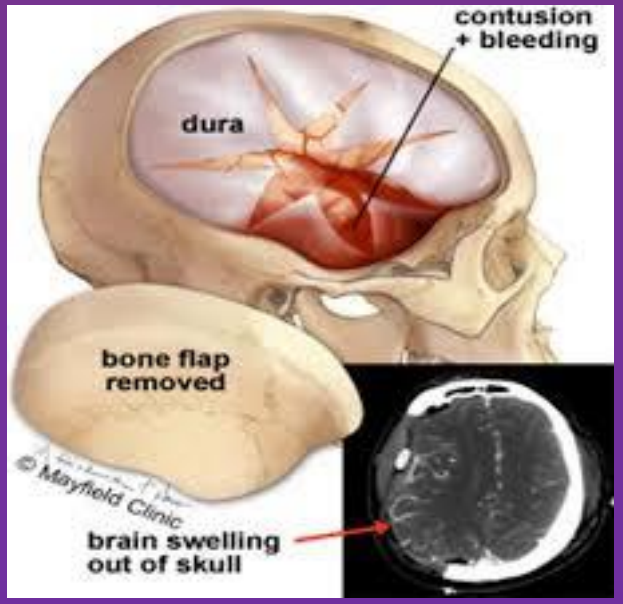
4th Brain trauma foundation guideline

Modalities	Level	Recommendation
Decompressive craniectomy	IIA	Bifrontal DC is not recommended to improve outcomes as measured by the Glasgow Outcome Scale–Extended (GOS-E) score at 6 months post-injury in severe TBI patients with diffuse injury (without mass lesions) Cooper DJ, Rosenfeld JV, Murray L, et al. Decompressive craniectomy in diffuse traumatic brain injury.[Erratum appears in N Engl J Med. 2011 Nov 24

Modalities	Level	Recommendation
Decompressive craniectomy	IIA	A large frontotemporoparietal DC (not less than 12 x 15 cm or 15 cm diameter) is recommended over a small frontotemporoparietal DC Shorter ICU stay Less ICP-targeting intervention Jiang JY, Xu W, Li WP, et al. Efficacy of standard trauma craniectomy for refractory intracranial hypertension with severe traumatic brain injury: a multicenter, prospective, randomized controlled study. *J Neurotrauma.* 2005 Qiu W, Guo C, Shen H, et al. Effects of unilateral decompressive craniectomy on patients with unilateral acute post-traumatic brain swelling after severe traumatic brain injury. *Crit Care.* 2009



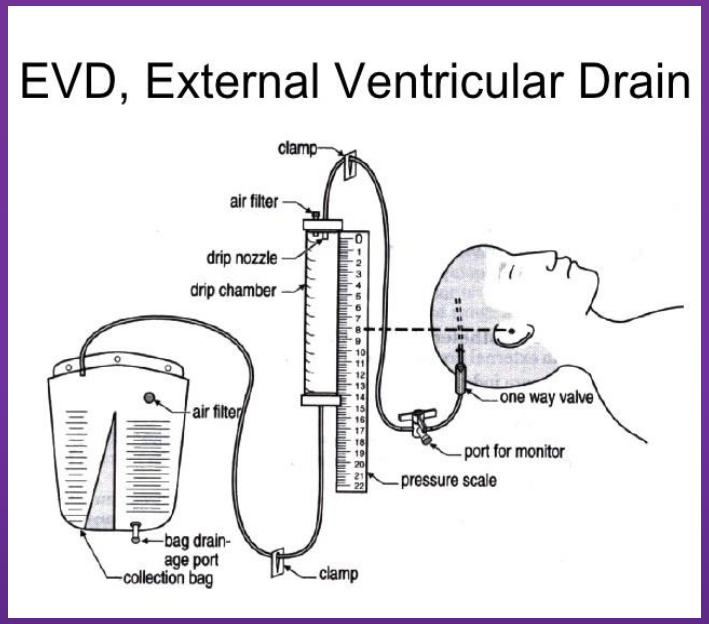
Bifrontal craniectomy



Frontotemporoparietal craniectomy

Modalities	Level	Recommendation
Hypothermia *Prophylactic* : early after injury and prior to intracranial pressure elevation *Therapeutic* : treatment for refractory intracranial pressure elevation	IIB	Early (within 2.5 hours), short-term (48 hours post-injury) prophylactic hypothermia is <u>not recommended</u> to improve outcomes in patients with diffuse injury Clifton GL, Valadka A, Zygun D, et al. Very early hypothermia induction in patients with severe brain injury (the National Acute Brain Injury Study: Hypothermia II): a randomised trial. *Lancet Neurol.* Feb 2011
Osmotherapy	***Recommendations from the Prior (3rd) Edition***	Mannitol is effective for control of raised intracranial pressure (ICP) at doses of 0.25 - 1 g/kg body weight Arterial hypotension (systolic blood pressure <90 mm Hg) should be avoided 4th edition : no recommendation : need further study

Modalities	Level	Recommendation
CSF drainage	III	An EVD system zeroed at the midbrain with continuous drainage of CSF may be considered to lower ICP burden more effectively than intermittent use Nwachuku EL, Puccio AM, Fetzick A, et al. Intermittent versus continuous cerebrospinal fluid drainage management in adult severe traumatic brain injury: assessment of intracranial pressure burden. *Neurocrit Care.* Aug 2013
		Use of CSF drainage to lower ICP in patients with an initial Glasgow Coma Scale (GCS) <6 during the first 12 hours after injury may be considered Griesdale DE, McEwen J, Kurth T, Chittock DR. External ventricular drains and mortality in patients with severe traumatic brain injury. *Can J Neurol Sci.* 2010



Modalities	Level	Recommendation
Ventilation therapy	IIB	Prolonged prophylactic hyperventilation with partial pressure of carbon dioxide in arterial blood (PaCO2) of 25 mm Hg or less is not recommended

Recommendations from the Prior (3rd) Edition Not Supported by Evidence Meeting Current Standards

Hyperventilation is recommended as a temporizing measure for the reduction of elevated intracranial pressure (ICP)

Hyperventilation should be avoided during the first 24 hours after injury

If hyperventilation is used

- monitor oxygen delivery
  - venous oxygen saturation (SjO2)
  - brain tissue O2 partial pressure (BtpO2)

Muizelaar JP, Marmarou A, Ward JD, et al. Adverse effects of prolonged hyperventilation in patients with severe head injury: a randomized clinical trial. *J Neurosurg.* Nov 1991

Modalities	Level	Recommendation
Anesthetics, Analgesics, and Sedatives	IIB	Administration of barbiturates to induce burst suppression as prophylaxis against the development of intracranial hypertension is not recommended
	IIB	High-dose barbiturate administration is recommended to control elevated ICP refractory to maximum standard medical and surgical treatment

Eisenberg HM, Frankowski RF, Contant CF, Marshall LF, Walker MD. High-dose barbiturate control of elevated intracranial pressure in patients with severe head injury. *J Neurosurg.* Jul 1988

Modalities	Level	Recommendation
Anesthetics, Analgesics, and Sedatives	IIB	Although propofol is recommended for the control of ICP, it is not recommended for improvement in mortality or 6-month outcomes Caution is required as high-dose propofol can produce significant morbidity

Proprofol infusion syndrome

- Unexplained metabolic acidosis
- Hypertriglyceridemia
- Hypotension
- Lactic acidosis
- Arrhythmia: sudden onset of marked bradycardia resistant to treatment
- Rhabdomyolysis
- Acute renal failure
- Hepatomegaly

Kelly DF, Goodale DB, Williams J, et al. Propofol in the treatment of moderate and severe head injury: a randomized, prospective double-blinded pilot trial. *J Neurosurg.* Jun 1999

Modalities	Level	Recommendation
Steroids	I	***The use of steroids is not recommended for improving outcome or reducing ICP*** In patients with severe TBI, high-dose methylprednisolone was associated with increased mortality and is contraindicated Edwards P, Arango M, Balica L, et al. Final results of MRC CRASH, a randomised placebo-controlled trial of intravenous corticosteroid in adults with head injury-outcomes at 6 months. *Lancet*. Jun 2005

Modalities	Level	Recommendation
Nutrition	-	Aim to achieve goal nutrition by the 5^{th}-7^{th} day
Infection prophylaxis	IIA	Early tracheostomy is recommended to reduce mechanical ventilation days No evidence early tracheostomy reduces mortality or the rate of nosocomial pneumonia

Bouderka MA, Fakhir B, Bouaggad A, Hmamouchi B, Hamoudi D, Harti A. Early tracheostomy versus prolonged endotracheal intubation in severe head injury. *J Trauma.* Aug 2004
Sugerman HJ, Wolfe L, Pasquale MD, et al. Multicenter, randomized, prospective trial of early tracheostomy. *J Trauma.* Nov 1997

Modalities	Level	Recommendation
Infection prophylaxis	IIA	The use of povidone-iodine (PI) oral care is not recommended to reduce VAP and may cause an increased risk of ARDS Seguin P, Tanguy M, Laviolle B, Tirel O, Malledant Y. Effect of oropharyngeal decontamination by povidone-iodine on ventilator-associated pneumonia in patients with head trauma. *Crit Care Med.* May 2006 Seguin P, Laviolle B, Dahyot-Fizelier C, et al. Effect of oropharyngeal povidone-iodine preventive oral care on ventilator-associated pneumonia in severely brain-injured or cerebral hemorrhage patients: a multicenter, randomized controlled trial. *Crit Care Med.* Jan 2014
	III	***Antimicrobial-impregnated catheters may be considered to prevent catheter-related infections during EVD*** Wang X, Dong Y, Qi XQ, Li YM, Huang CG, Hou LJ. Clinical review: Efficacy of antimicrobialimpregnated catheters in external ventricular drainage - a systematic review and meta-analysis. *Crit Care.* 2013 Ratilal BO, Costa J, Sampaio C, Pappamikail L. Antibiotic prophylaxis for preventing meningitis in patients with basilar skull fractures. *Cochrane Databse Syst Rev.* Aug 2011. PMID: 21833952.

Modalities	Level	Recommendation
DVT prophylaxis	III	Low molecular weight heparin (LMWH) or low-dose unfractioned heparin ***may be used*** in combination with mechanical prophylaxis Increased risk for expansion of intracranial hemorrhage

Kwiatt ME, Patel MS, Ross SE, et al. Is low-molecular-weight heparin safe for venous thromboembolism prophylaxis in patients with traumatic brain injury? A Western Trauma Association multicenter study. *J Trauma Acute Care Surg.* Sep 2012

Mohseni S, Talving P, Lam L, Chan LS, Ives C, Demetriades D. Venous thromboembolic events in isolated severe traumatic brain injury. *J Emerg Trauma Shock.* Jan 2012

Scudday T, Brasel K, Webb T, et al. Safety and efficacy of prophylactic anticoagulation in patients with traumatic brain injury. *J Am Coll Surg.* 2011

Daley MJ, Brown CV. Late venous thromboembolism prophylaxis after craniotomy in acute traumatic brain injury *Am Surg* 2015

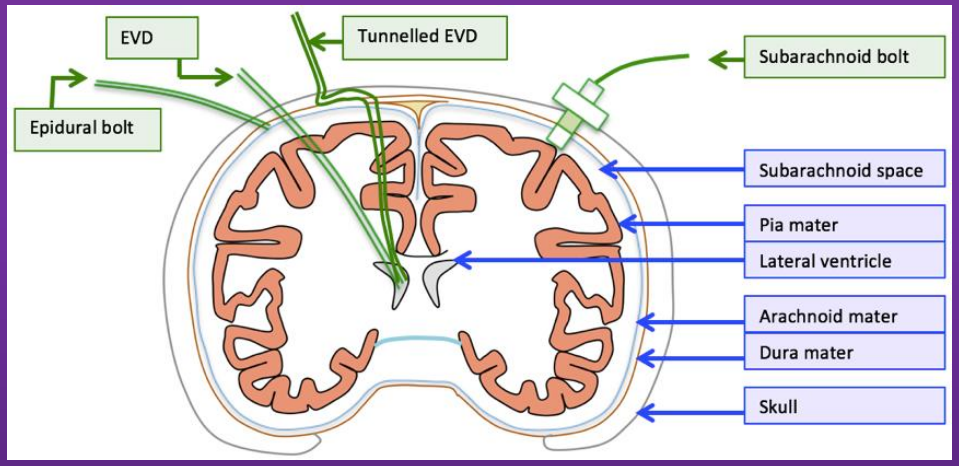
Modalities	Level	Recommendation
Seizure prophylaxis	IIA	Prophylactic use of phenytoin or valproate is not recommended for preventing *late* PTS Phenytoin is ***recommended to decrease the incidence of early PTS (within 7 days of injury)***

Inaba K, Menaker J, Branco BC, et al. A prospective multicenter comparison of levetiracetam versus phenytoin for early posttraumatic seizure prophylaxis. *J Trauma Acute Care Surg.* Mar 2013

Dikmen SS, Machamer JE, Winn HR, Anderson GD, Temkin NR. Neuropsychological effects of valproate in traumatic brain injury: a randomized trial. *Neurology.* Feb 2000

Temkin NR, Dikmen SS, Wilensky AJ, Keihm J, Chabal S, Winn HR. A randomized, double-blind study of phenytoin for the prevention of post-traumatic seizures. *N Engl J Med.* Aug 1990

Modalities	Level	Recommendation
Intracranial Pressure Monitoring	IIB	Management of severe TBI patient using information from ICP monitoring is recommended to reduce in-hospital and 2-week post-injury mortality



(Farahvar A, Gerber LM, Chiu YL, Carney N, Hartl R, Ghajar J. Increased mortality in
patients with severe traumatic brain injury treated without intracranial pressure
monitoring. J Neurosurg. Oct 2012;117(4):729-734. PMID: 22900846.)

Modalities	Level	Recommendation
Cerebral perfusion pressure monitoring	IIB	CPP monitoring is recommended to decrease 2-week mortality Gerber LM, Chiu YL, Carney N, Hartl R, Ghajar J. Marked reduction in mortality in patients with severe traumatic brain injury. J Neurosurg. Dec 2013
CPP = MAP – ICP		
Advanced Cerebral Monitoring	III	Jugular bulb monitoring of arteriovenous oxygen content difference (AVDO2), as a source of information for management decisions, may be considered to reduce mortality and improve outcomes at 3 and 6 months post-injury

Cruz J. The first decade of continuous monitoring of jugular bulb oxyhemoglobin saturation: management strategies and clinical outcome. Crit Care Med. Feb 1998

Le Roux PD, Newell DW, Lam AM, Grady MS, Winn HR. Cerebral arteriovenous oxygen difference: a predictor of cerebral infarction and outcome in patients with severe head injury. J Neurosurg. 1997

Robertson C. Desaturation episodes after severe head injury: influence on outcome. Acta Neurochir Suppl (Wien). 1993

Robertson CS, Gopinath SP, Goodman JC, Contant CF, Valadka AB, Narayan RK. SjvO2 monitoring in head-injured patients. J Neurotrauma. Oct 1995

Modalities	Level	Recommendation
Blood pressure Threshold	III	SBP at ≥100 mm Hg for patients 50 to 69 years old SBP ≥110 mmHg for patients 15 to 49 or over 70 years old to decrease mortality and improve outcomes Berry C, Ley EJ, Bukur M, et al. Redefining hypotension in traumatic brain injury.Injury. Nov 2012
Intracranial Pressure	IIB	Treating ICP above 22 mm Hg is recommended because values above this level are associated with increased mortality(Level2B) Sorrentino E, Diedler J, Kasprowicz M, et al. Critical thresholds for cerebrovascular reactivity after traumatic brain injury. Neurocrit Care. 2012

Modalities	Level	Recommendation
Intracranial Pressure	III	A combination of ICP values and clinical and brain CT findings may be used to make management decisions Chambers IR, Treadwell L, Mendelow AD.Determination of threshold levels of cerebral operating characteristic curves: an observational study in 291 patients. J Neurosurg. Mar 2001
Cerebral perfusion pressure (CPP)	IIB	Cerebral perfusion pressure (CPP) value for survival and favorable outcomes is between 60 and 70 mm Hg. Allen BB, Chiu YL, Gerber LM, Ghajar J, Greenfield JP. Age-specific cerebral perfusion pressure thresholds and survival in children and adolescents with severe traumatic brain injury. Pediatr Crit Care Med. Jan 2014

Modalities	Level	Recommendation
Cerebral perfusion pressure (CPP)	III	Avoiding aggressive attempts to maintain CPP > 70 mm Hg with fluids and pressors may be considered because of the risk of adult respiratory failure Johnnson U, Nilsson P, Ronne-Engstrom E, Howells T, Enblad P. Favorable outcome in traumatic brain injury patients with impaired cerebral pressure autoregulation when treated at low cerebral perfusion pressure levels. Neurosurg. Mar 2011
Advanced Cerebral Monitoring Thresholds	III	Jugular venous saturation of <50% may be a threshold to avoid in order to reduce mortality and improve outcomes Robertson C. Desaturation episodes after severe head injury: influence on outcome. Acta Neurochir Suppl (Wien). 1993

Management of traumatic brain injury

General management: Summary

Decompressive craniectomy

Bifrontal craniectomy

Hemicraniectomy
12 X 15 cm

Prophylactic hypothermia

Osmotherapy

20% mannitol 0.25-1 g/kg

 Hyperventilation

Anesthetics, Analgesics, and Sedatives

 Burst suppression prophylaxis

✓ Treatment of refractory IICP

 **Steriods**

Nutrition ✓ Add-on within 5-7th day

Early tracheostomy is recommended to reduce mechanical ventilation days

Infection prophylaxis

✓

Antimicrobial-impregnated catheters may be considered to prevent catheter-related infections during EVD

DVT prophylaxis

✓

Low molecular weight heparin (LMWH) or low-dose unfractioned heparin ***may be used*** in combination with mechanical prophylaxis
Increased risk for expansion of intracranial hemorrhage

Seizure prophylaxis

✓ AED first 7 days for EARLY seizure prophylaxis

 AED for late seizure prophylaxis

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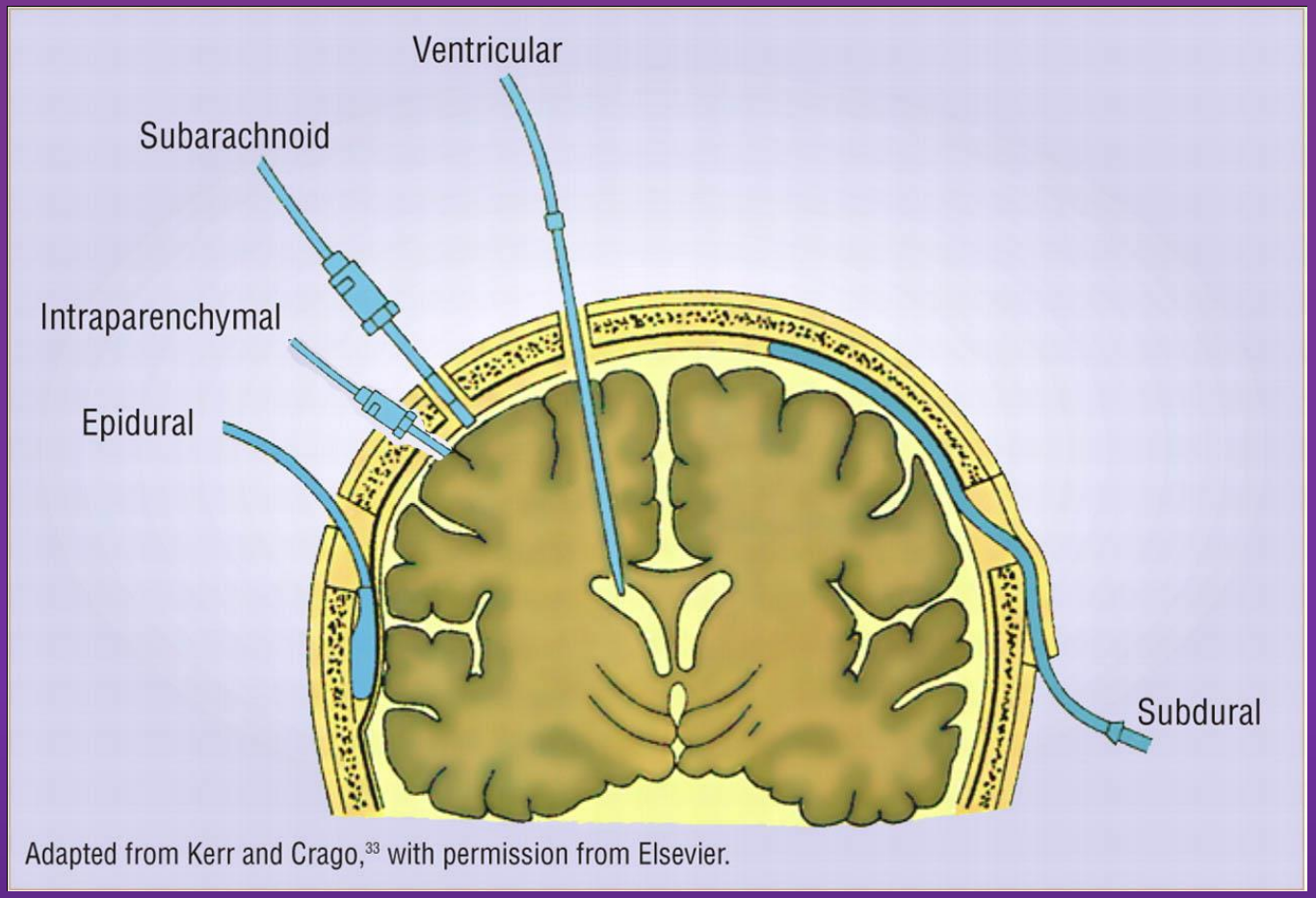
ICP monitoring

When???

✓ Severe HI with abnormal CT

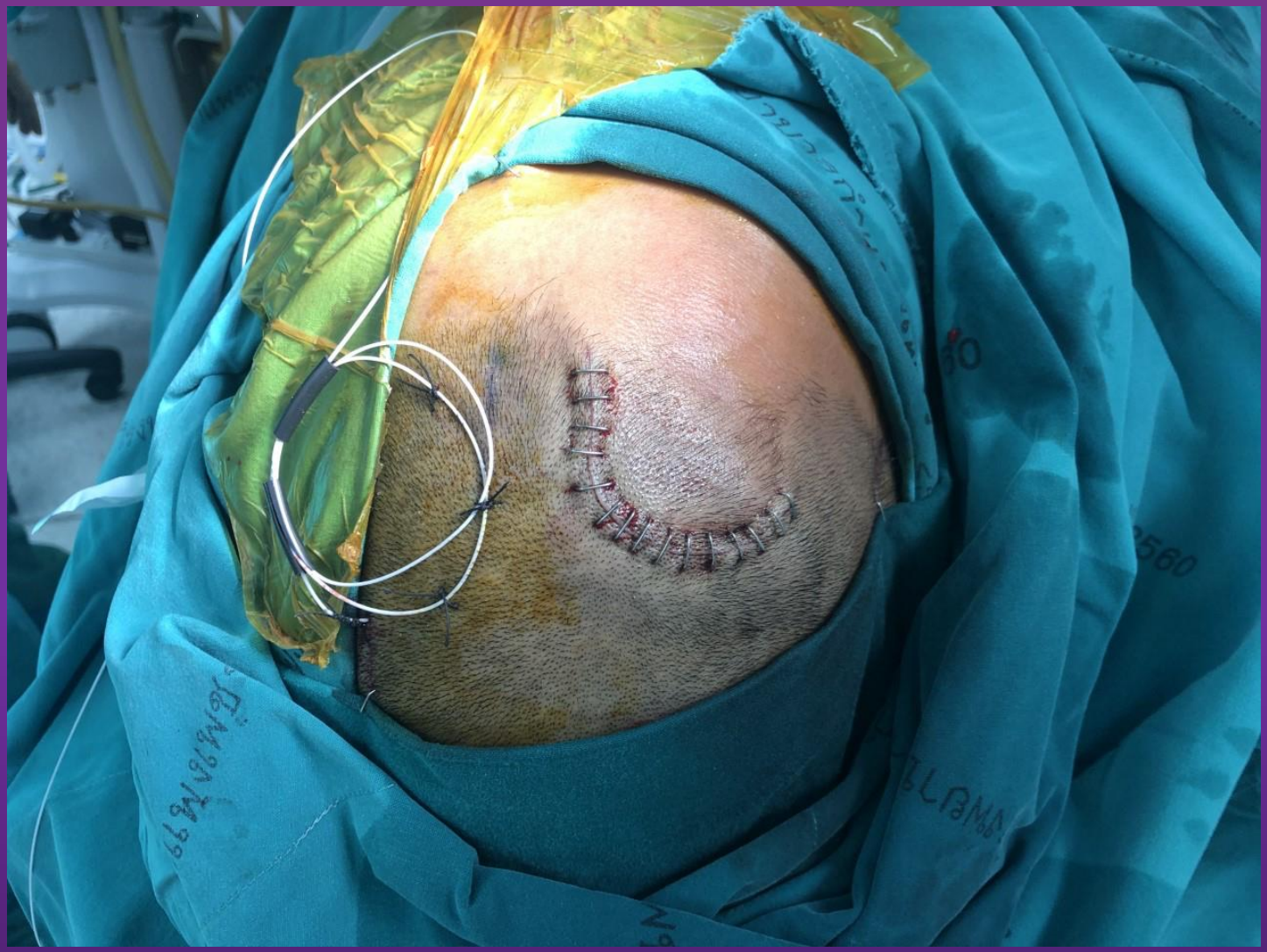
✓ Severe HI with normal CT and 2 of followings

- Age > 40 yrs
- Abnormal posturing
- SBP < 90



Adapted from Kerr and Crago,[33] with permission from Elsevier.

Treatment if ICP more than 22 mmHg



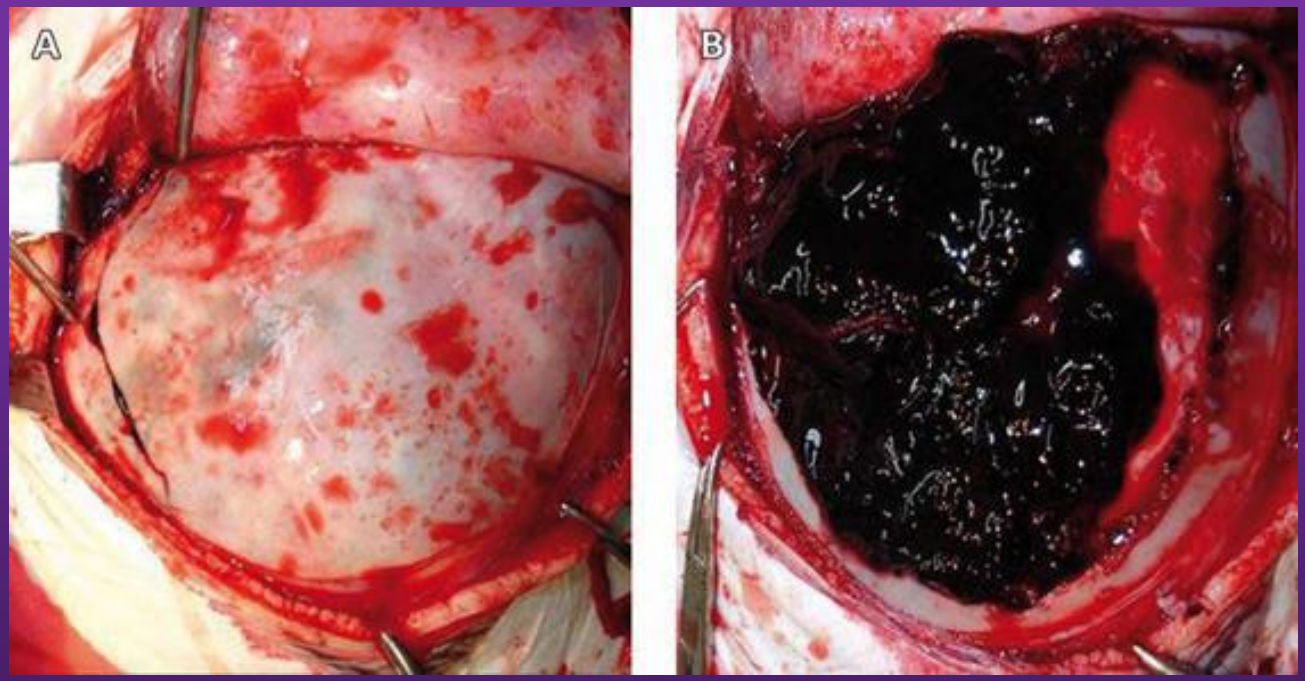
Blood pressure	SBP at ≥100 mm Hg for patients 50 to 69 years old
	SBP ≥110 mmHg for patients 15 to 49 or over 70 years old to decrease mortality and improve outcomes
CPP	Optimum 60-70 mmHg
SjVO2	Jugular venous saturation of <50% reduce mortality rate

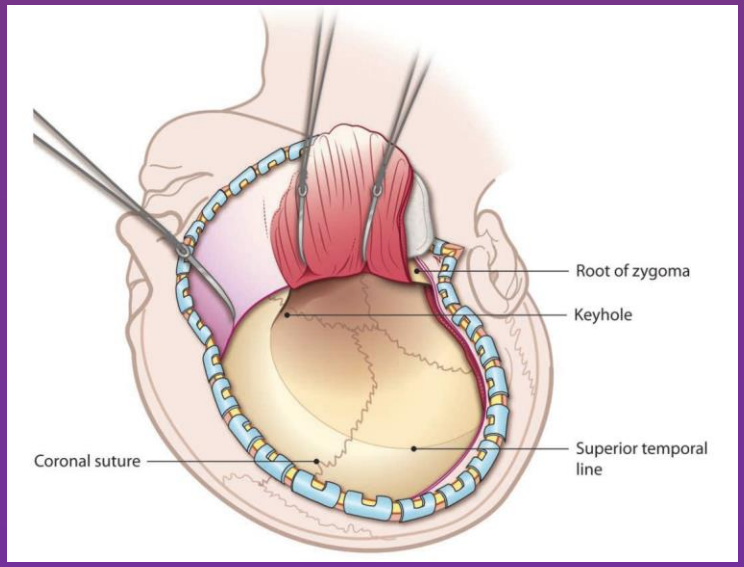
Specific management

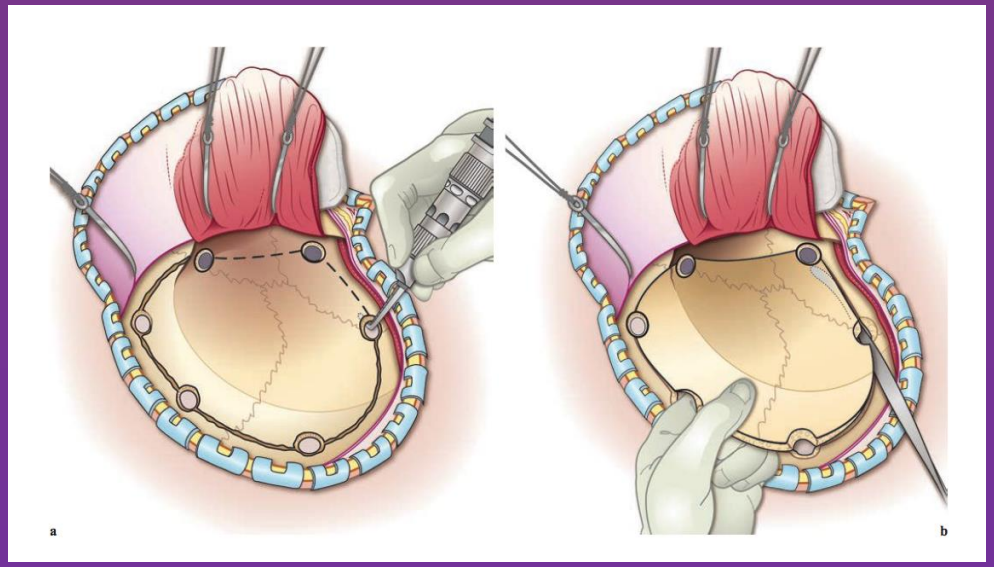
Epidural hematoma	Surgical indication

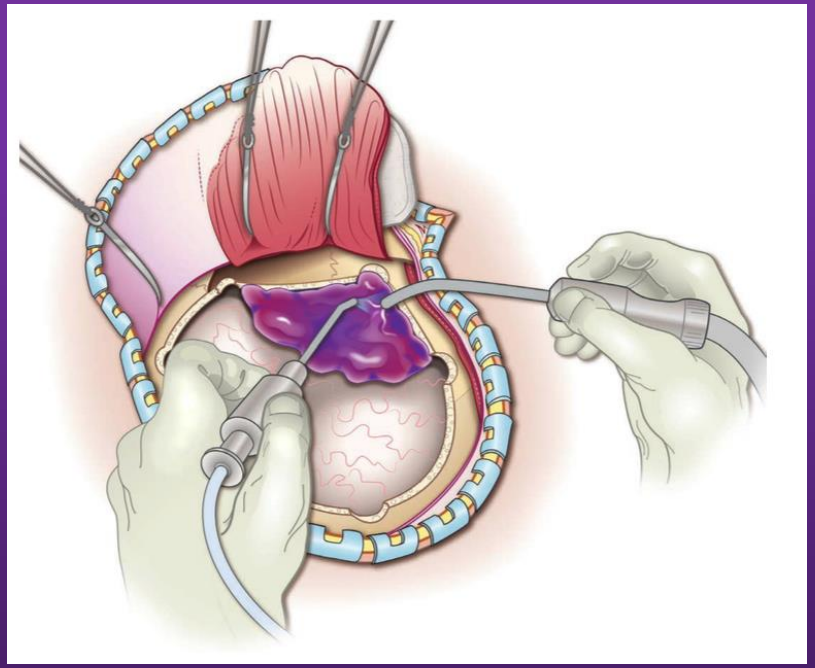
Volume greater than 30cc should be evacuated regardless of GCS

Volume less than 30cc/less than 15mm thickness/less than 5mm midline shift/GCS greater than 8 may be managed non-operatively




Root of zygoma
Keyhole
Coronal suture
Superior temporal line


a
b

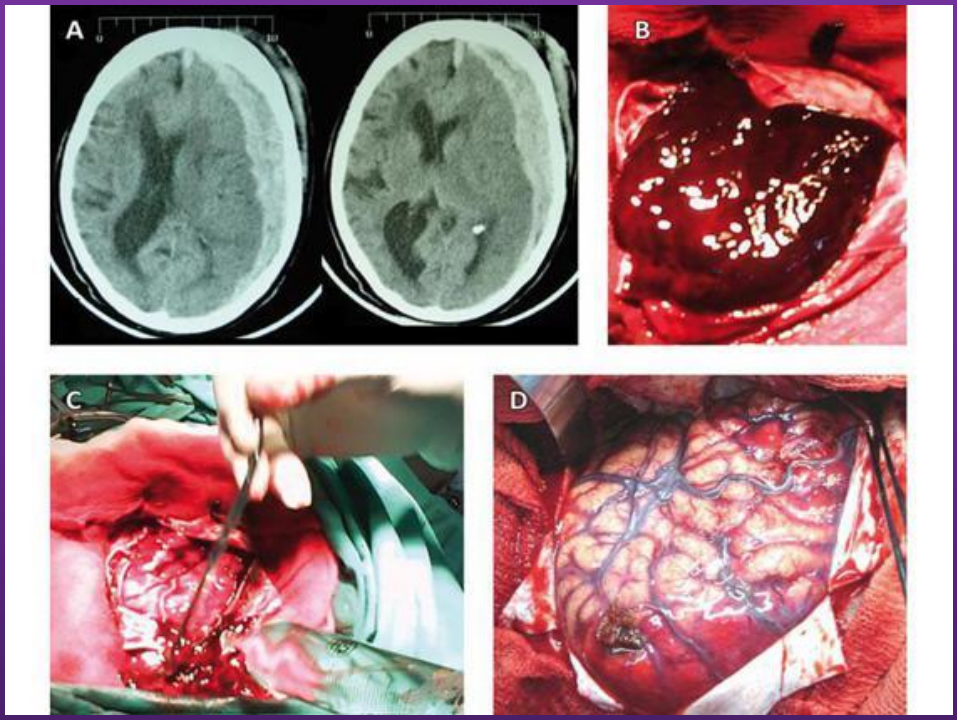


Subdural hematoma | Surgical indication

SDH with thickness > 10mm/midline shift > 5mm should be evacuated regardless of GCS

Patients with acute SDH and GCS < 9 should have ICP monitoring

SDH with thickness < 10mm or < 5mm midline shift should be evacuated if GCS drops 2 or more points from injury to admission, pupillary function is abnormal, or ICP> 20 mm Hg

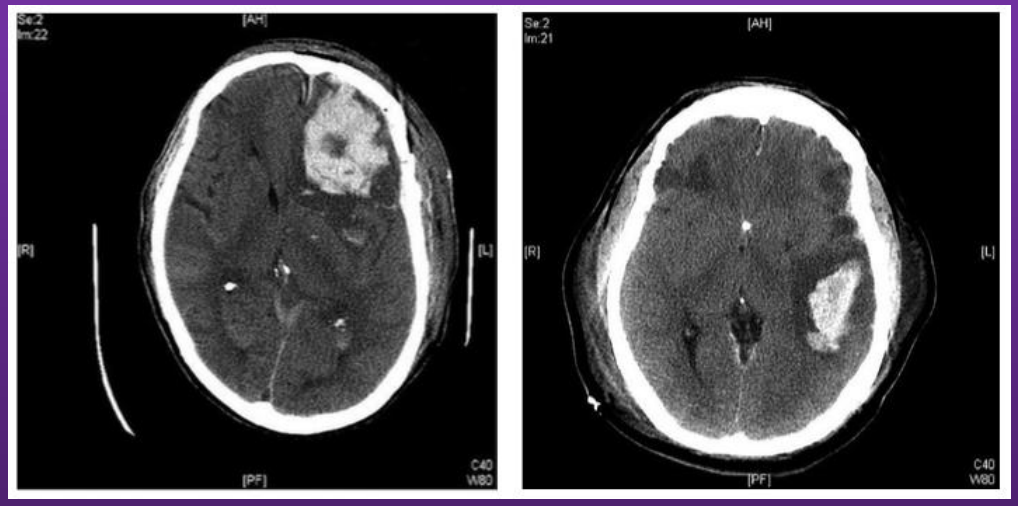


Traumatic parenchymal lesions | Surgical indication

Parenchymal mass lesion with referable neurologic deterioration, medically refractory intracranial hypertension or signs of mass effect on CT should be evacuated

Patients with GCS 6-8, with frontal or temporal lesion volume > 20cc with midline shift >5mm or cisternal compression, or <u>any</u> lesion volume > 50cc should be evacuated

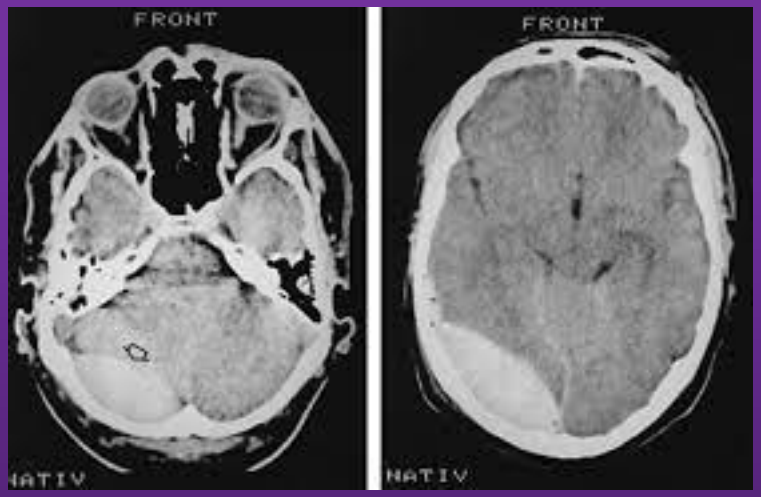
Parenchymal mass lesions without clinical neurologic compromise, with no signs of mass effect and with controlled ICP can be treated non-operatively

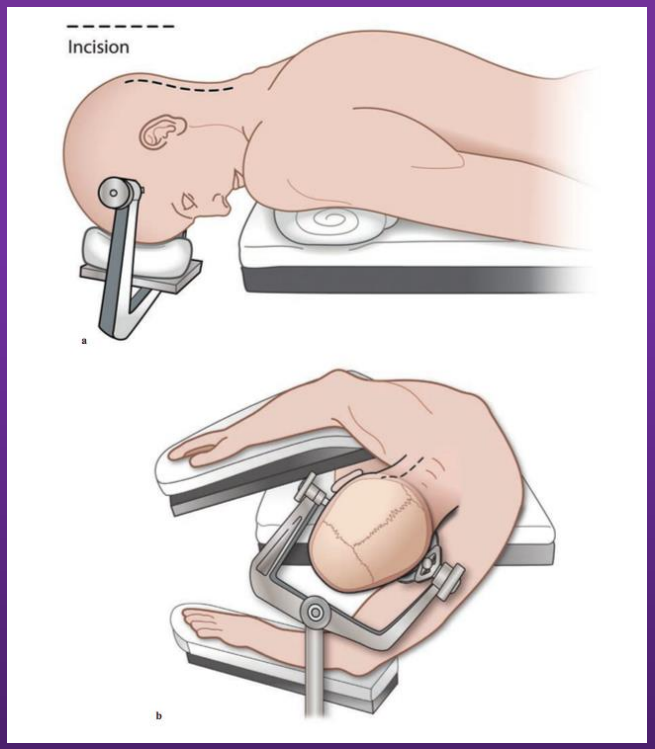


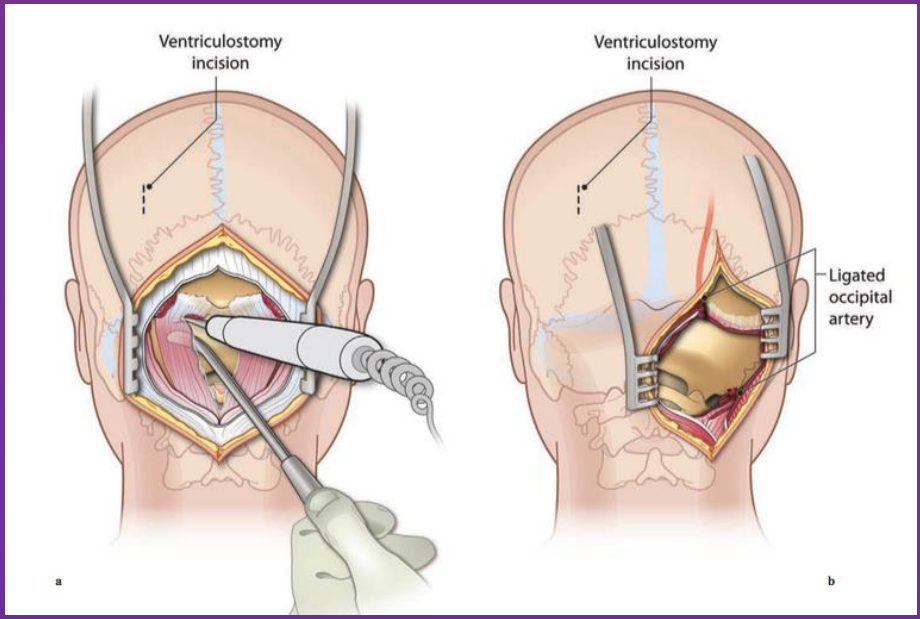
Posterior Fossa Mass Lesions | Surgical indication

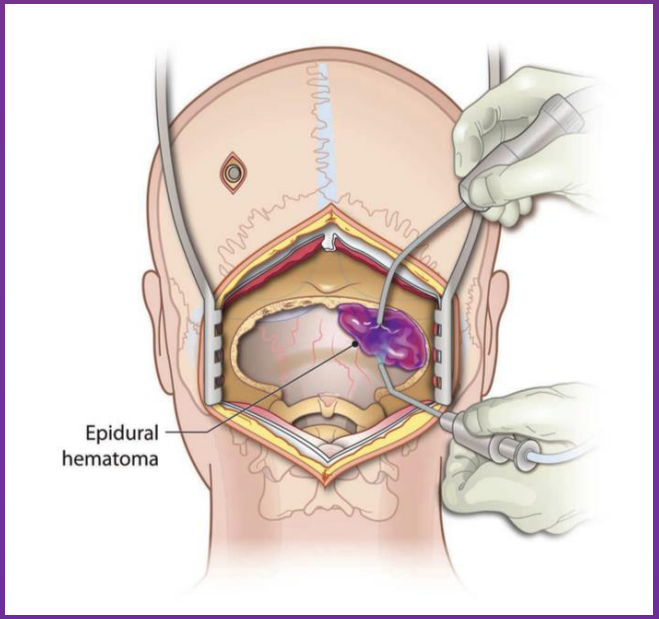
Patients with mass effect on CT or neurologic dysfunction or deterioration referable to a lesion should undergo evacuation; **"mass effect"** is defined as distortion of the 4th ventricle, effacement of basilar cisterns or obstructive hydrocephalus

Patients without mass effect of neurologic dysfunction may be treated non-operatively






Ventriculostomy incision
Ventriculostomy incision
Ligated occipital artery
a
b

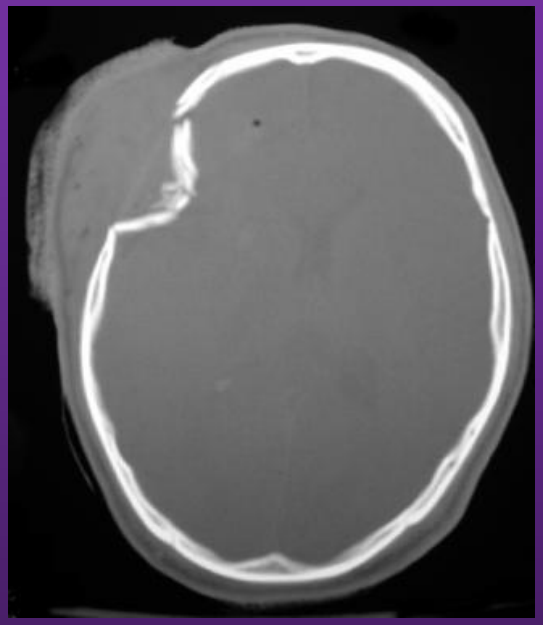

Epidural hematoma

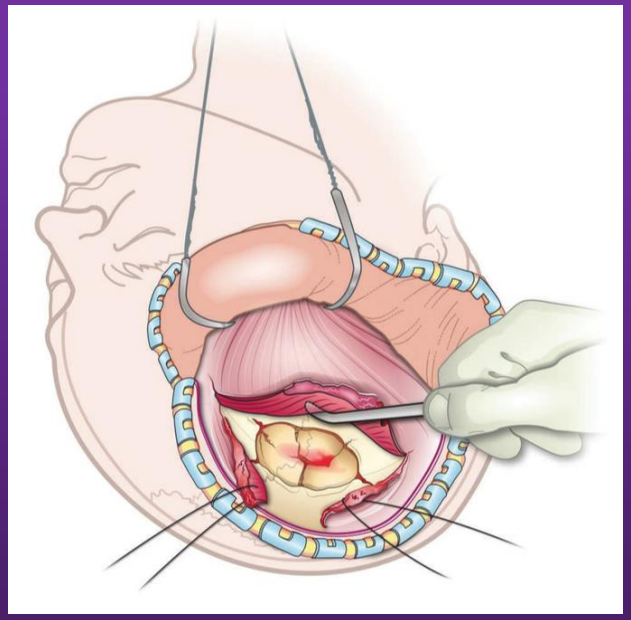
Depressed skull fracture | Surgical indication

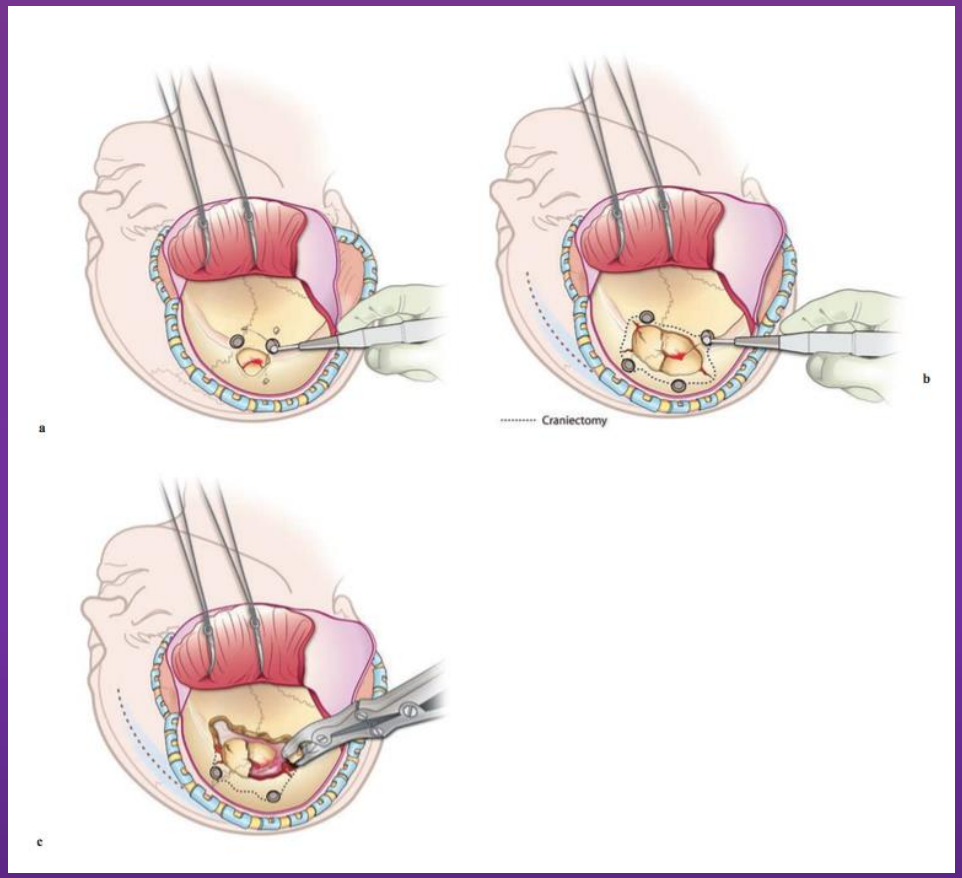
Open fractures with depression greater than the thickness of the skull should be treated surgically to prevent infection

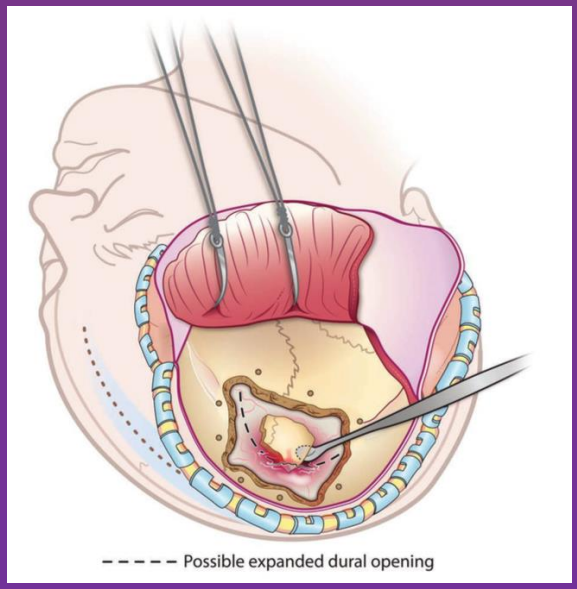
Open depressed skull fractures may be treated non-operatively provided there is no evidence of dural penetration, intraparenchymal hematoma, depression > 1 cm, frontal sinus involvement, gross cosmetic deformity, wound infection, pneumocephalus, or gross wound contamination

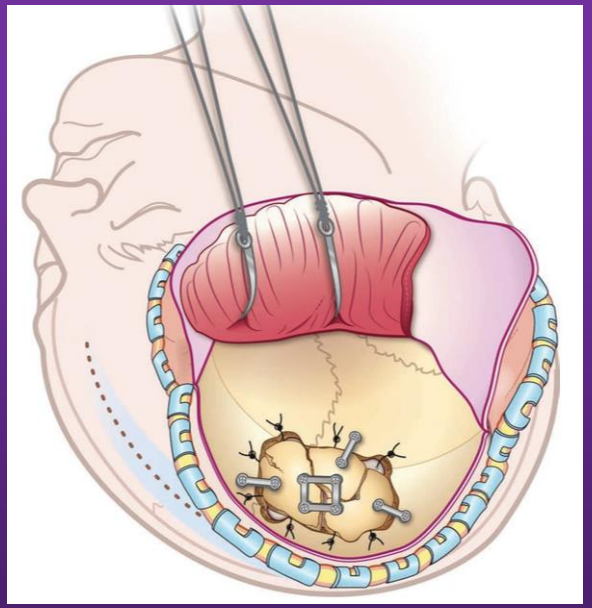
Closed depressed skull fractures may be treated non-operatively






a
b
Craniectomy
c


Possible expanded dural opening



OR preparation

Blood component

- Packed red cell
- Fresh frozen plasma(if needed)
- Platelet(if needed)

Antibiotics

- Standard: Cefazolin 25 mg/Kg/dose 30 min prior to incision
- Alternative: Fosfomycin 2 g 30 min prior to incision

Scalp preparation

- Standard: Clipper at the time of surgery

Special consideration

- Reversal of anticoagulant
- Blood component for antiplatelet reversal

Medication

- Seizure prophylaxis: Phenytoin, Levetiracitam, Fosphenytoin, Valproic acid etc.
- Brain relaxation: 20% mannitol 0.25-1 g/kg/dose

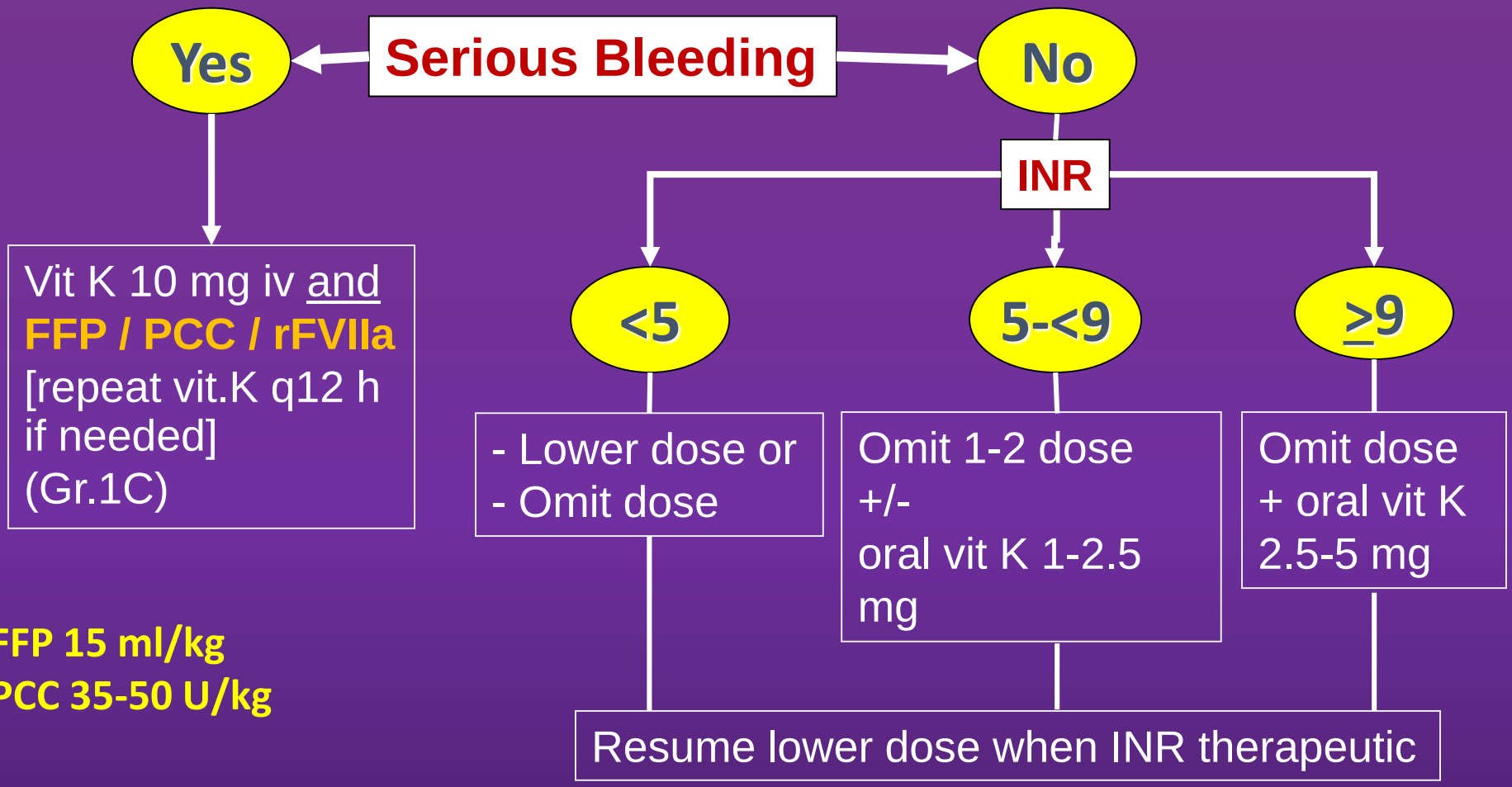
Warfarin Reversal

Time of reversal	Option	Remark
10-15 min	PCC	4-factor PCC is better than 3-factor PCC (low FVII)
60-150 min	FFP	Partial correction
6-8 hours	IV vitamin K	
24 hours	Oral vitamin K	
Few days	Stop warfarin	

PCC

Target INR	Current INR	Dose (U/kg)
Normal	1.5-2.5	30
	2.6-3.5	35
	>3.5	50
1.4-2.0	1.5-2.5	15
	2.6-3.5	25
	3.6-10	30
	>10	40

Warfarin reversal



FFP 15 ml/kg
PCC 35-50 U/kg

GI, GU bleed → Endoscopy for occult lesion

Reversal of LMWH

Last dose < 12 hr (single dose of LMWH)
Last dose < 20 hr (repeated Rx doses of LMWH)

- **Stop LMWH 12-24 hr**
- **Check Cr, APTT**

- **Protamine**
- **Check Cr, APTT, Anti-Xa**
- **rFVIIa if uncontrolled bleeding**
- **No FFP use**
- **(Future: Andexanet alfa)**

Looking for and Correct
- Local bleeding problem
- Concomitant platelet disorder

Protamine sulfate
- Max. 50 mg/dose
- Infusion < 5 mg/min

AANS step of treatment of malignant intracranial hypertension

CSF drainage — Level II

↓

Sedation and analgesia — Level III

↓

Mannitol — Level II

↓

Hyperventilation — Level III

$PaCO_2$ 30-35 mmHg

↓

Barbiturate coma — Level III